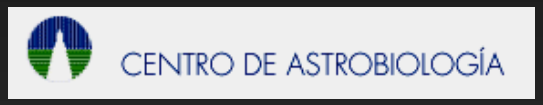
Fe K diagnostics in accreting BHs

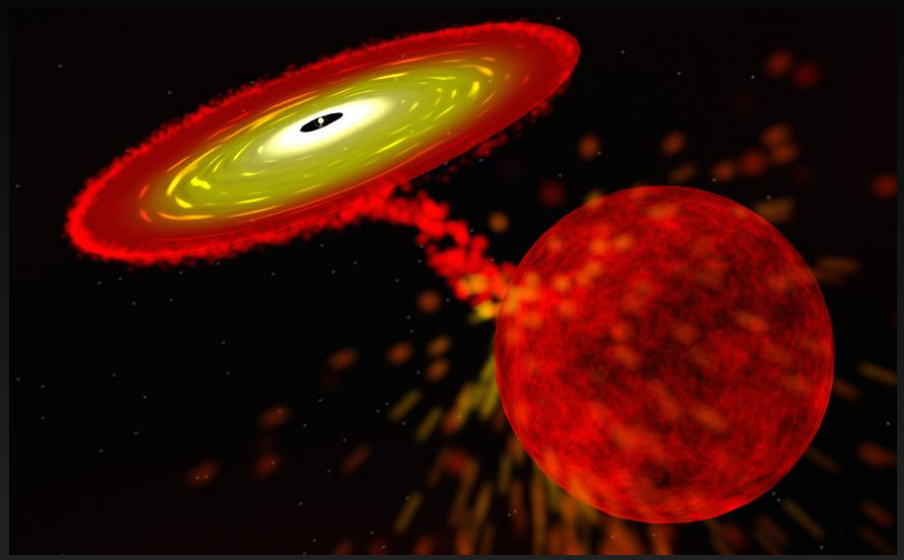
Giovanni Miniutti

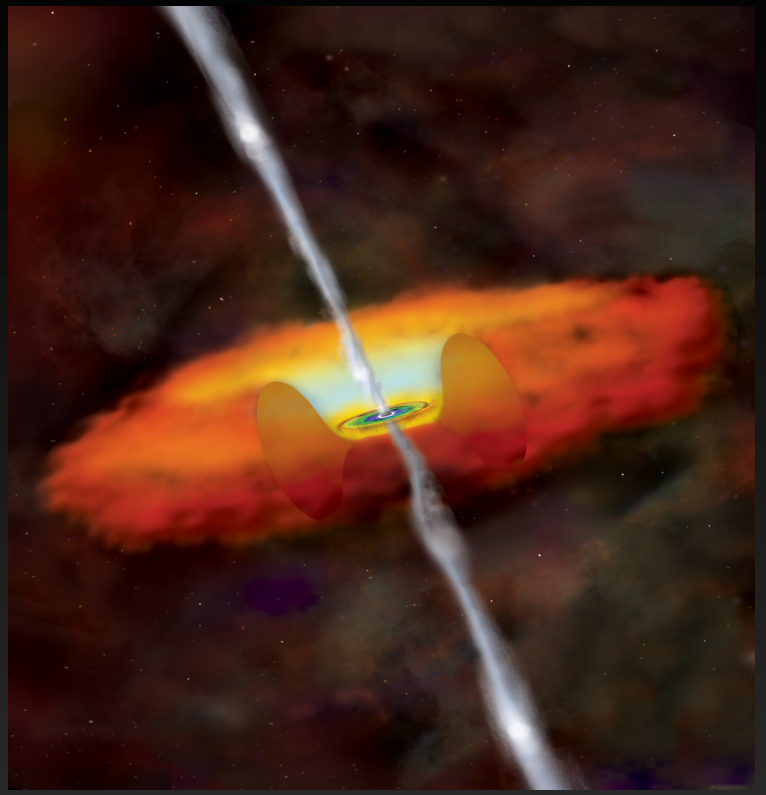


IXO Science Meeting – Paris – Apr 2010

CENTRO DE ASTROBIOLOGÍA

Accreting BHs





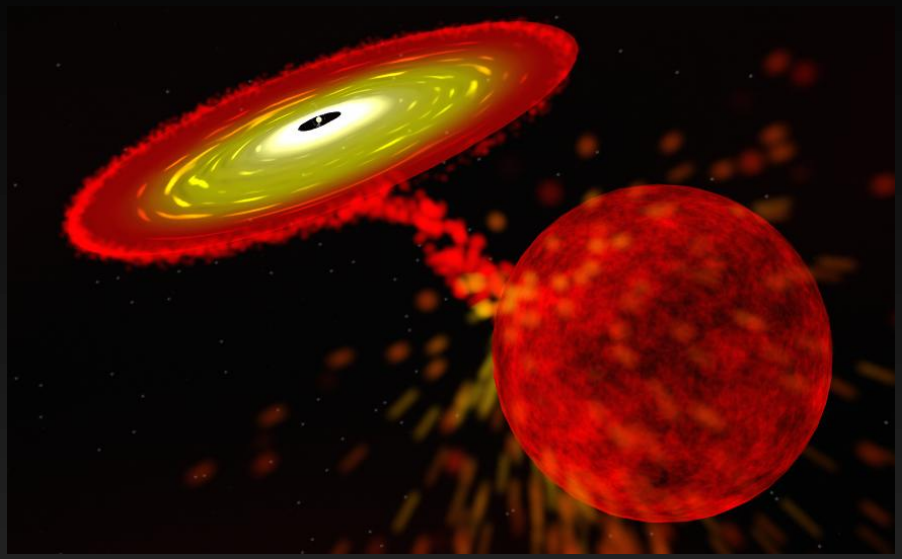
The two flavours of accreting BH:

stellar mass BHs scattered in galaxies (X-ray binaries)
supermassive BHs in the center of galaxies (AGN and quasars)

Close to the BH, most of the physical processes are the same
we can learn a great deal by comparing the two families

CENTRO DE ASTROBIOLOGÍA

Accreting BHs



Remark on X-ray binaries and IXO calorimeter (input from Maria Diaz-Trigo):

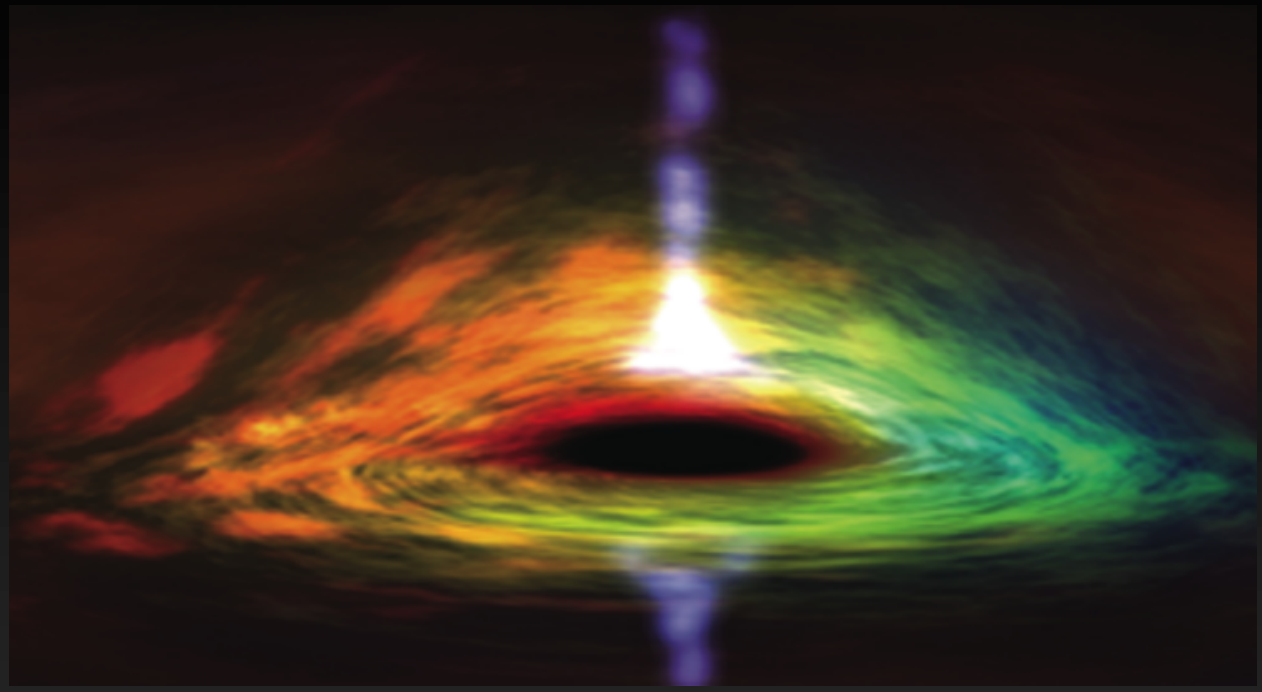
disc winds observed in BH binaries (+ 1 NS) at fluxes > 0.25-0.5 Crab

generally speaking, these fluxes are typical for high states BUT seem to be well above the current flux limits for the calorimeter

are we at risk of loosing potentially crucial science?

CENTRO DE ASTROBIOLOGÍA

Accreting BHs

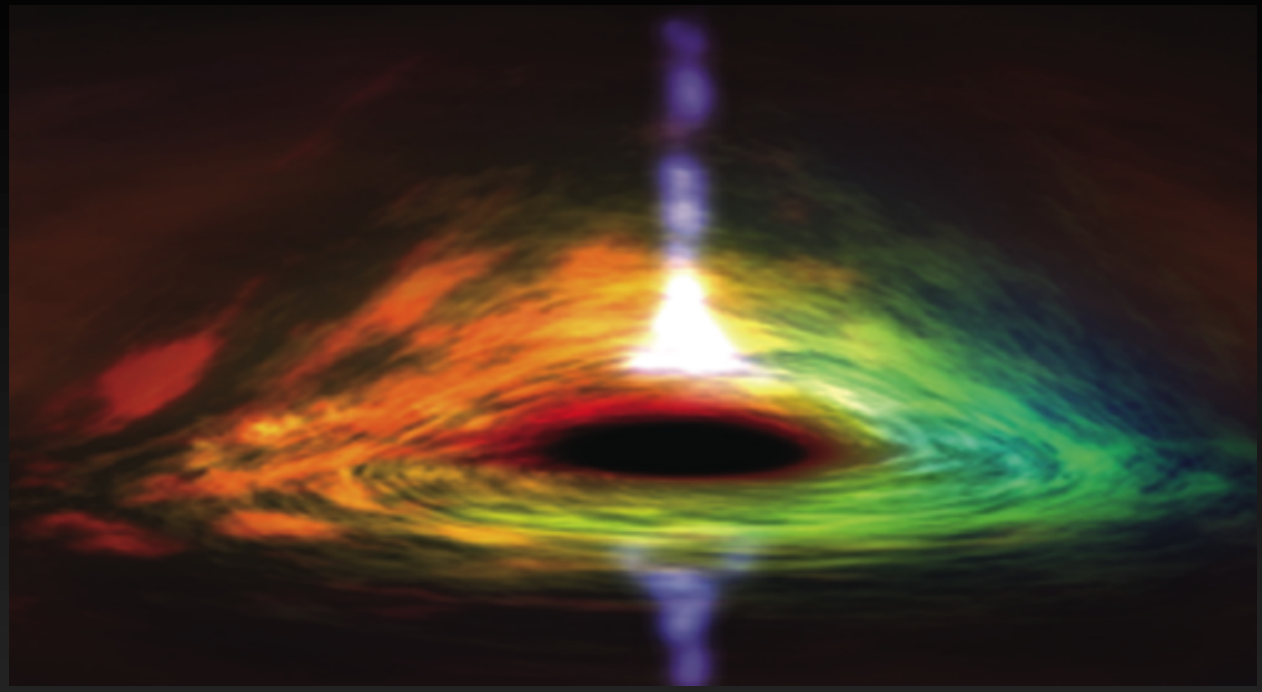


Open questions (some):

how does matter behave in the strong GR field regime?
does it always obey GR predictions?
what are the processes near the event horizon? (accretion/ejection)
do BH spin? How does the spin affect the emission/jet processes?
how are BH spins distributed? (BH birth/growth)
. . . . . .

CENTRO DE ASTROBIOLOGÍA

Accreting BHs

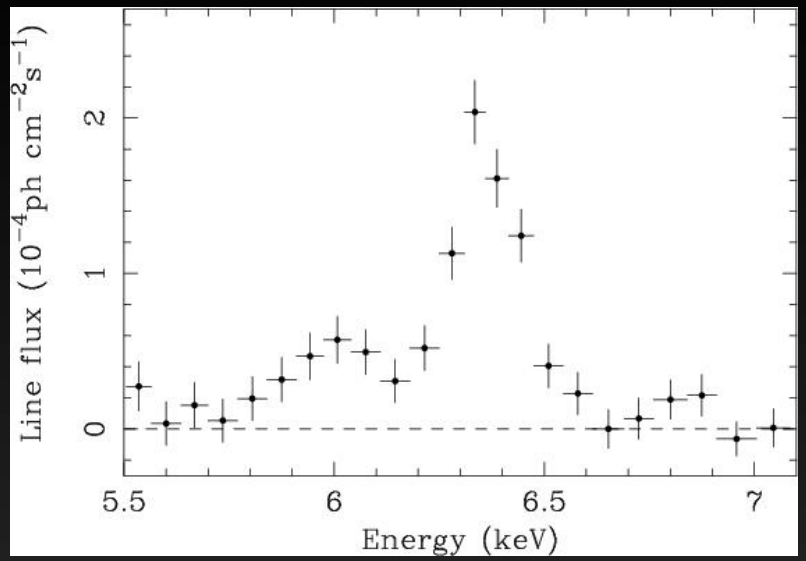


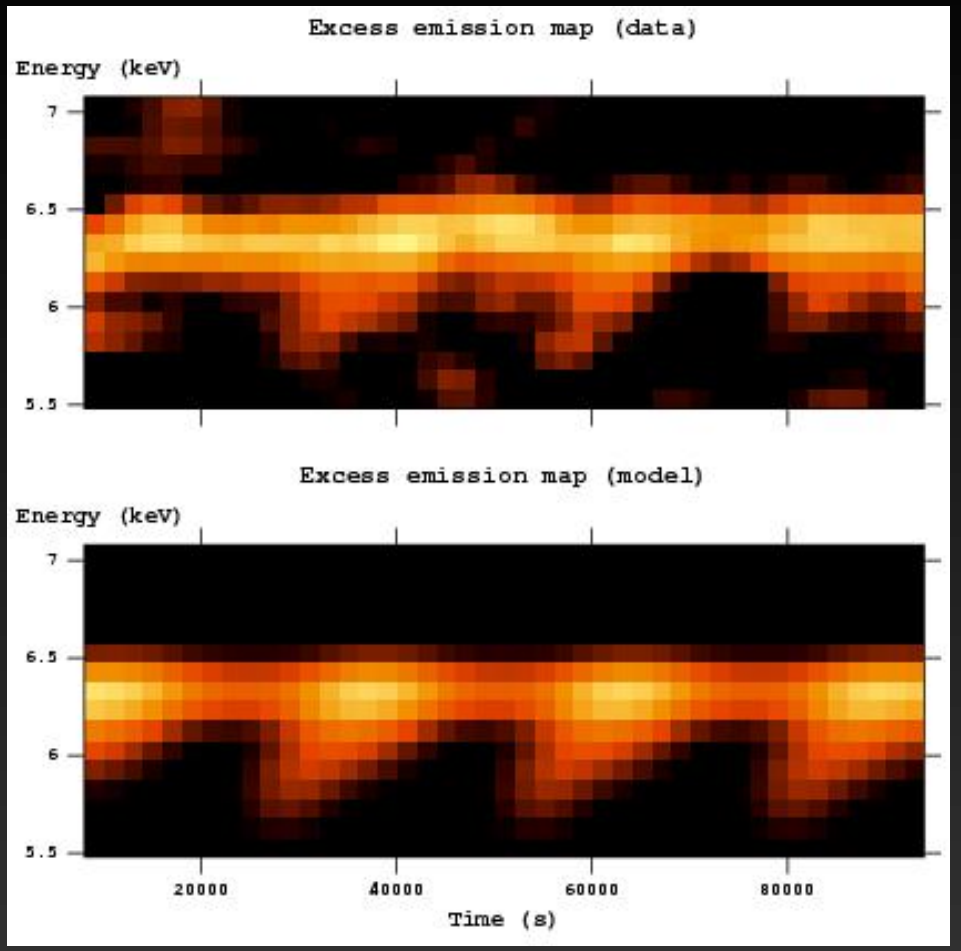
X-ray tools (some):

broadband disc/reflection spectra
relativistic (= broad) emission lines
narrow emission/absorption lines (red- and/or blue- shifted)
variability and reverberation
polarimetry
. . . . . .

CENTRO DE ASTROBIOLOGÍA

Dynamics in the strong GR regime

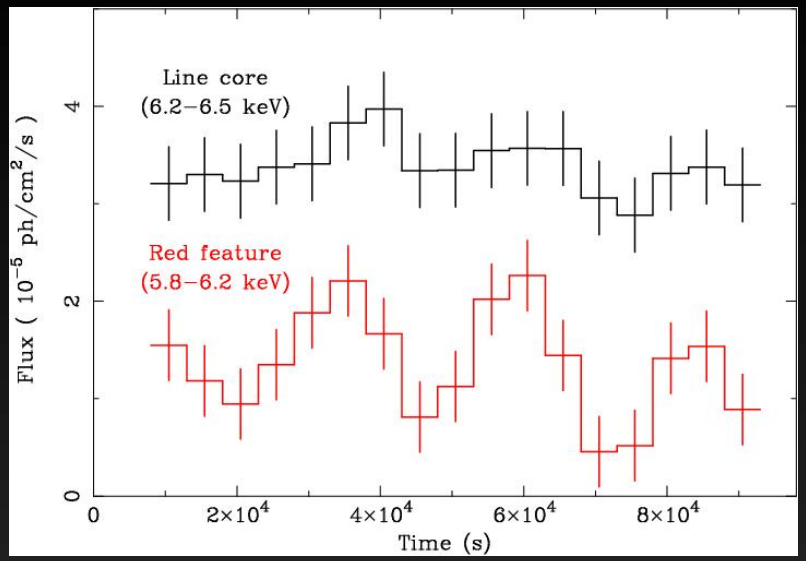


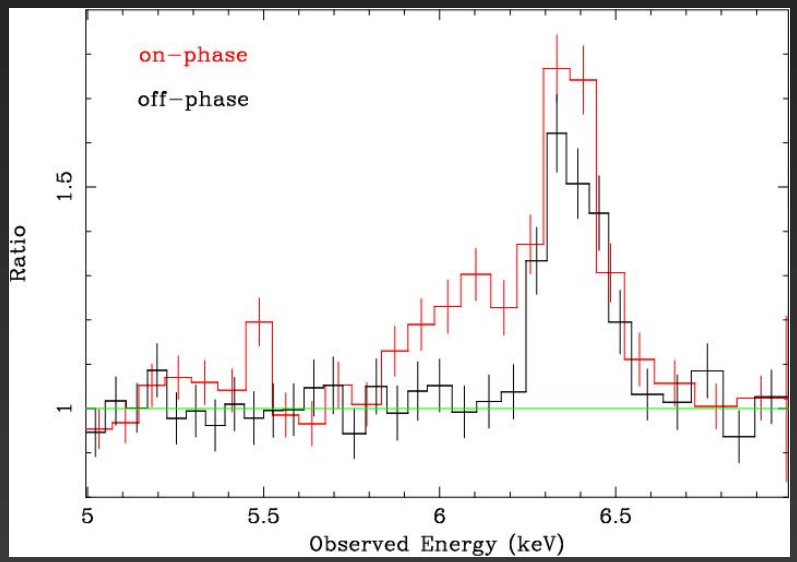


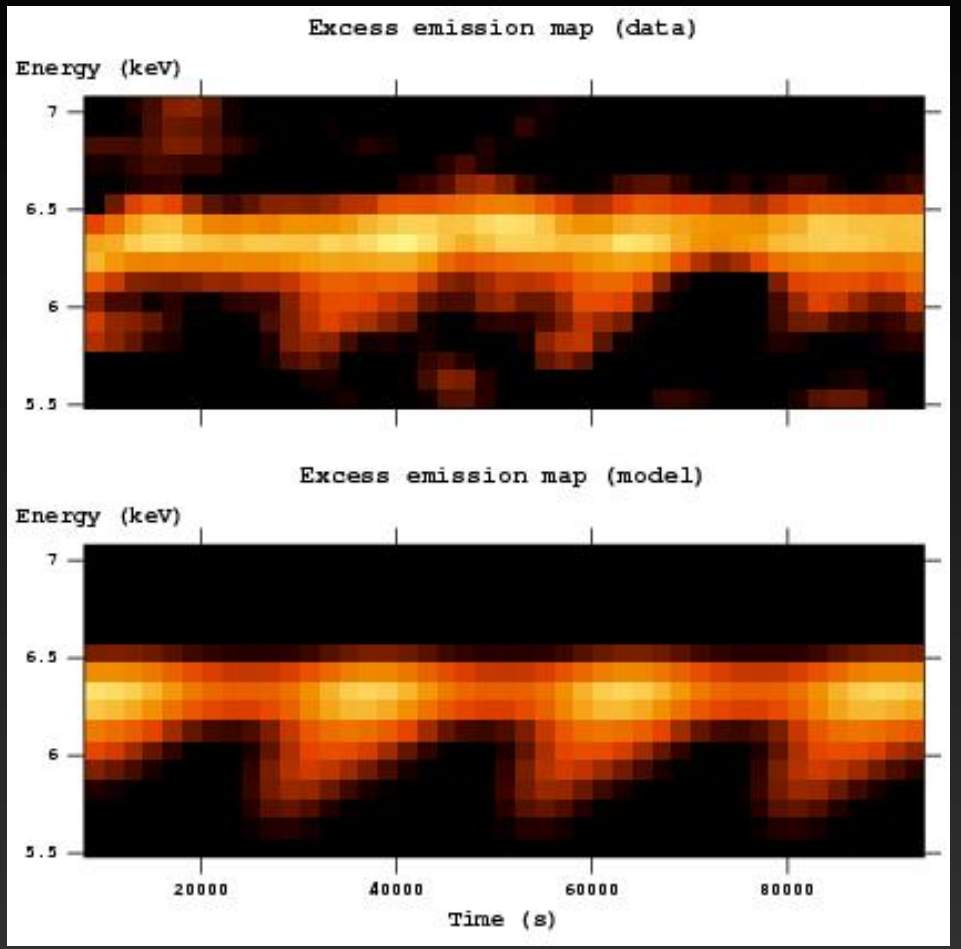
Iwasawa, GM & Fabian 04

CENTRO DE ASTROBIOLOGÍA

Dynamics in the strong GR regime





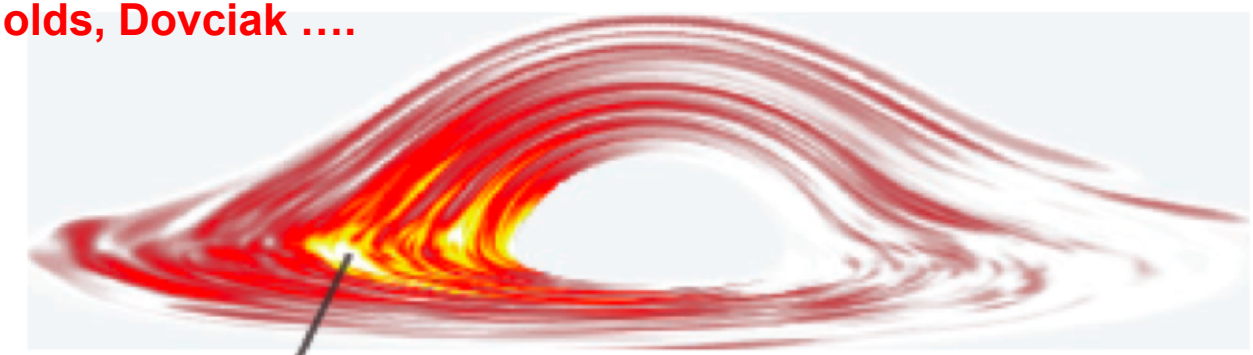


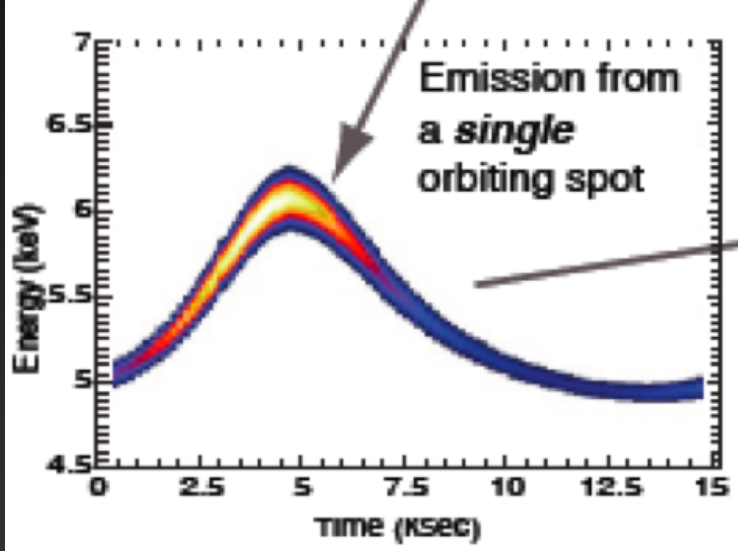
Iwasawa, GM & Fabian 04

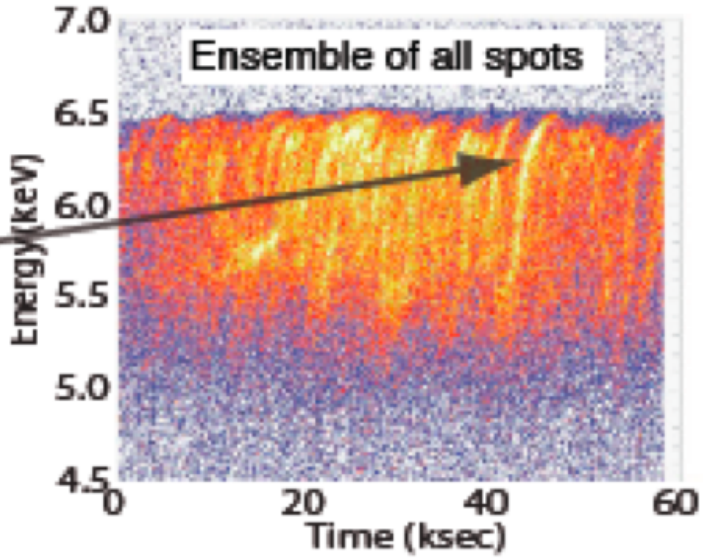
CENTRO DE ASTROBIOLOGÍA

Dynamics in the strong GR regime

Reynolds, Dovciak ….



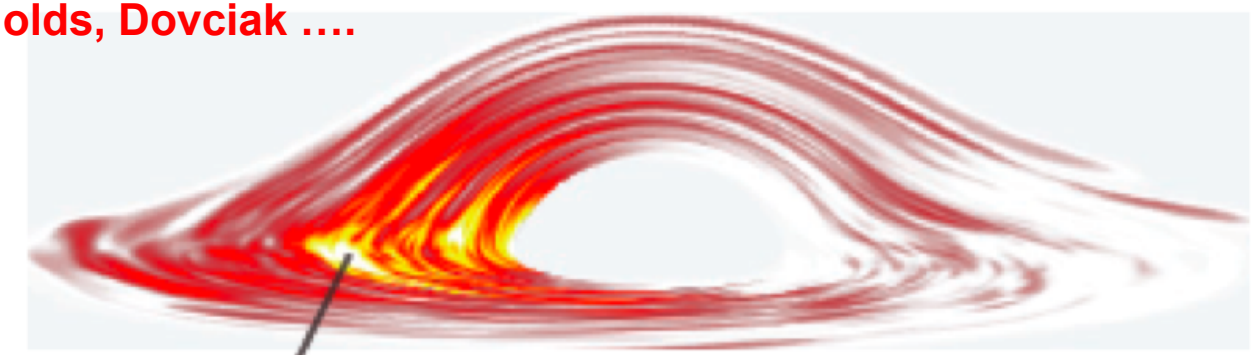


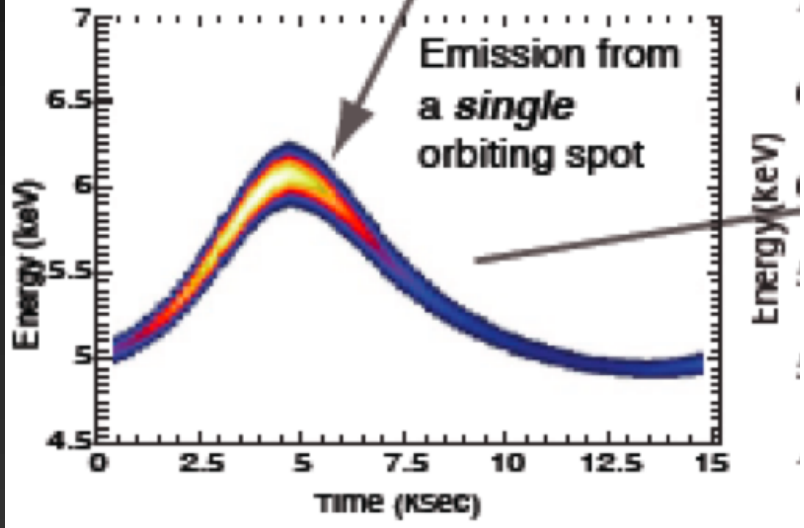


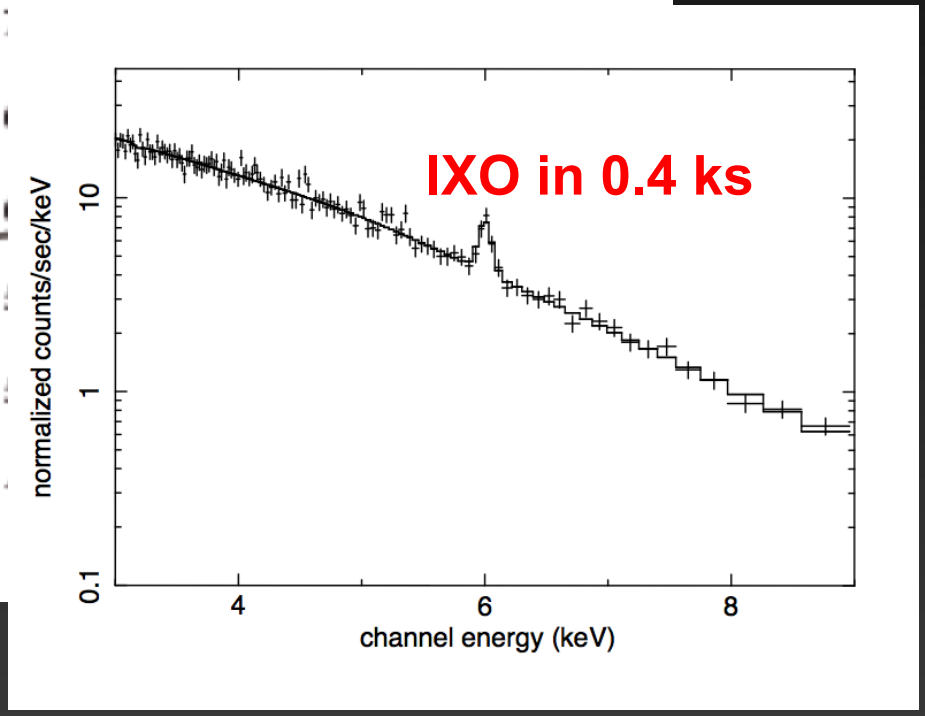
CENTRO DE ASTROBIOLOGÍA

Dynamics in the strong GR regime

Reynolds, Dovciak ….

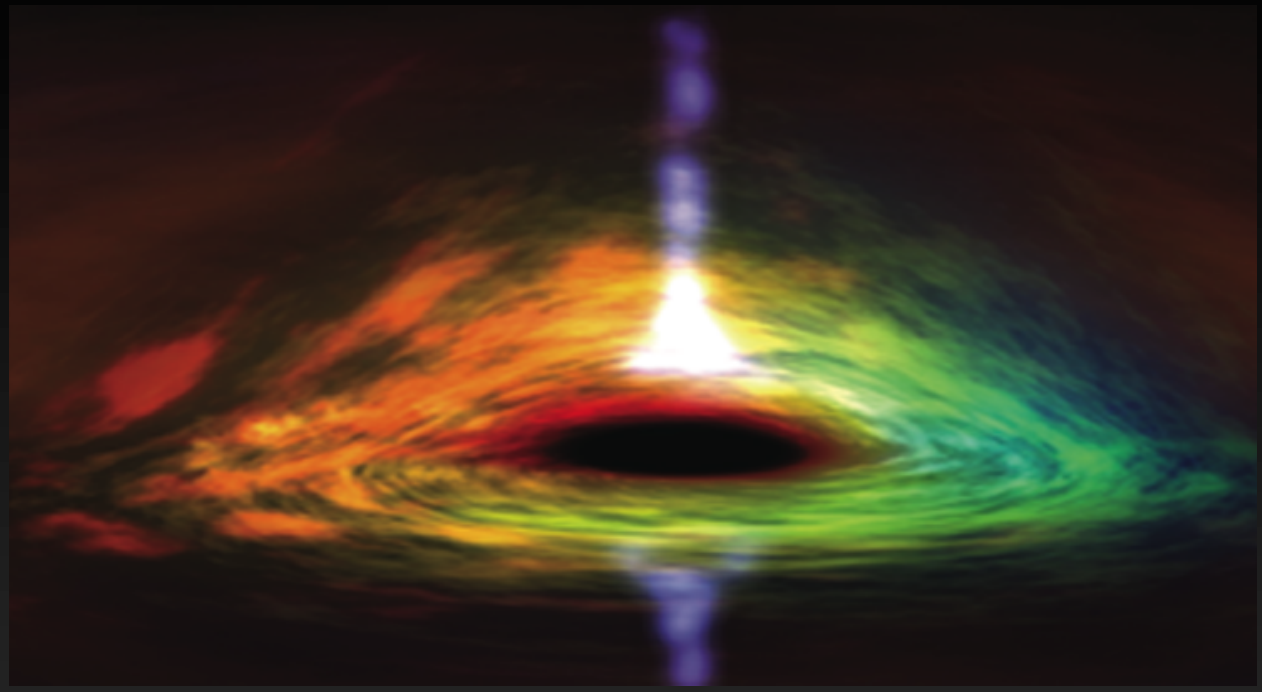






CENTRO DE ASTROBIOLOGÍA

BH spin



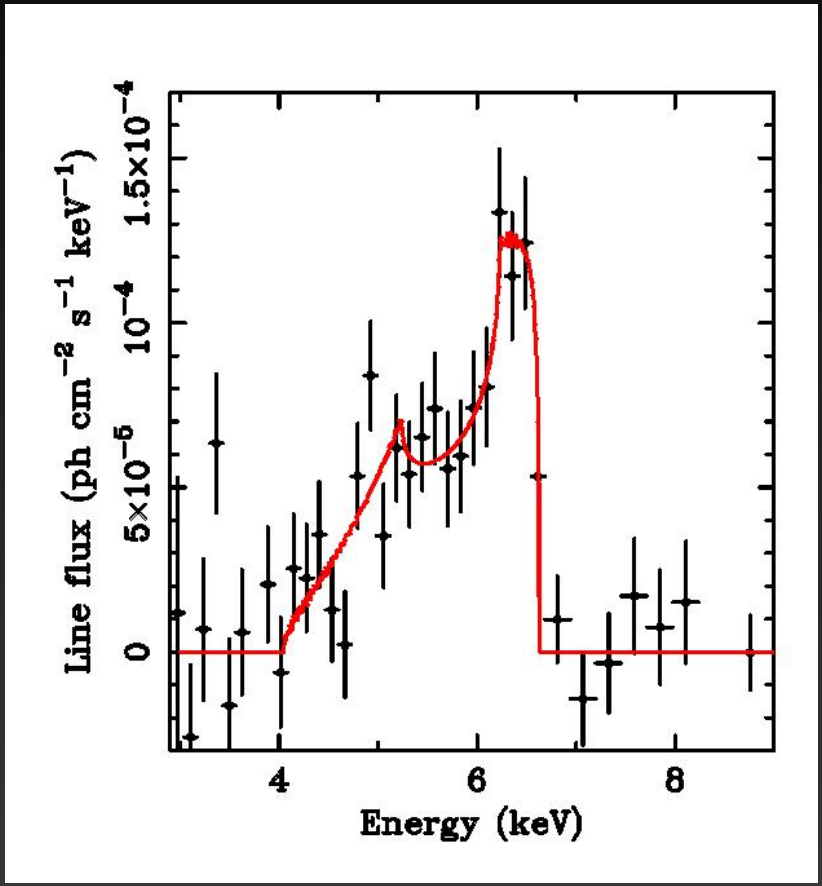
Why caring about the BH spin ?:

stellar mass BHs	dynamics of BH formation in supernovae
supermassive BHs	jets ? prograde vs. retrograde accretion ?
	relative importance of mergers and accretion
	accretion modes (coherent vs chaotic)

CENTRO DE ASTROBIOLOGÍA

The usual suspect: MCG-6-30-15

First clear detection of relativistic Fe K line (Tanaka et al 95) and first evidences for a rapidly spinning Kerr BH (Iwasawa et al 96, 99)

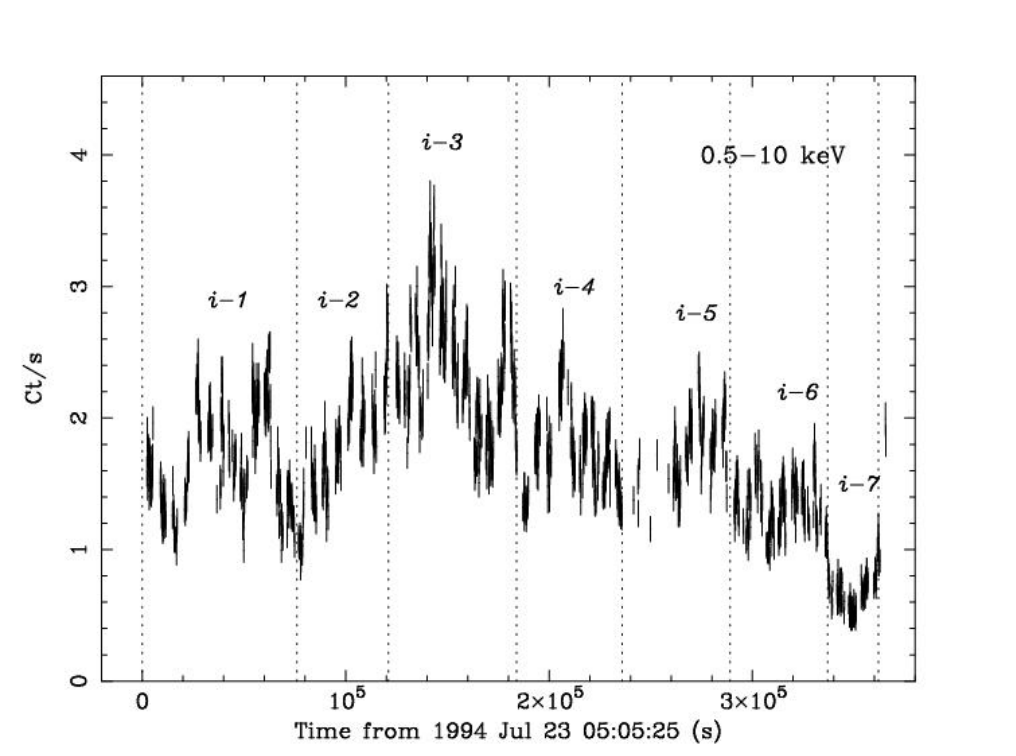


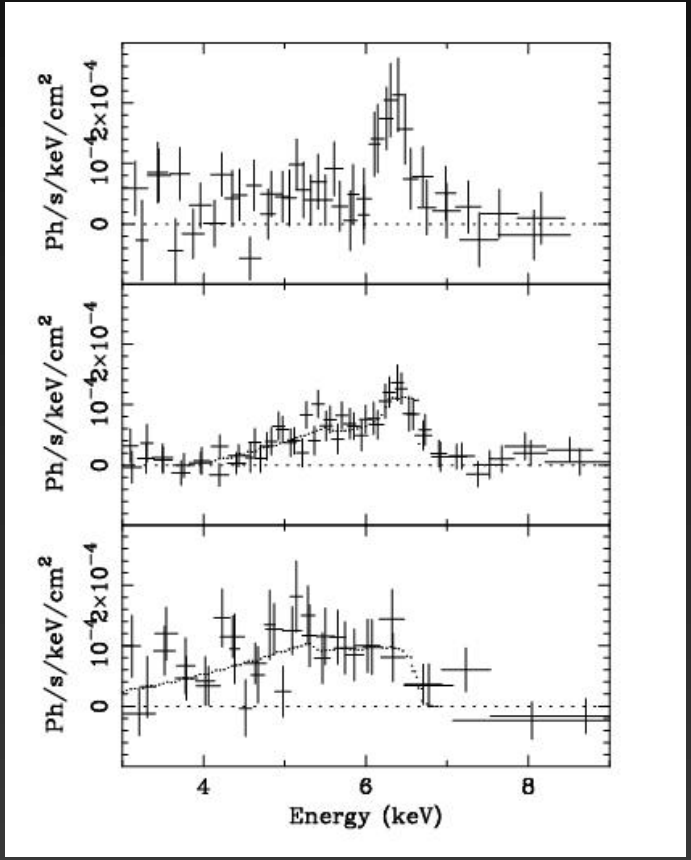
Tanaka et al 95

CENTRO DE ASTROBIOLOGÍA

The usual suspect: MCG-6-30-15

First clear detection of relativistic Fe K line (Tanaka et al 95) and first evidences for a rapidly spinning Kerr BH (Iwasawa et al 96, 99)



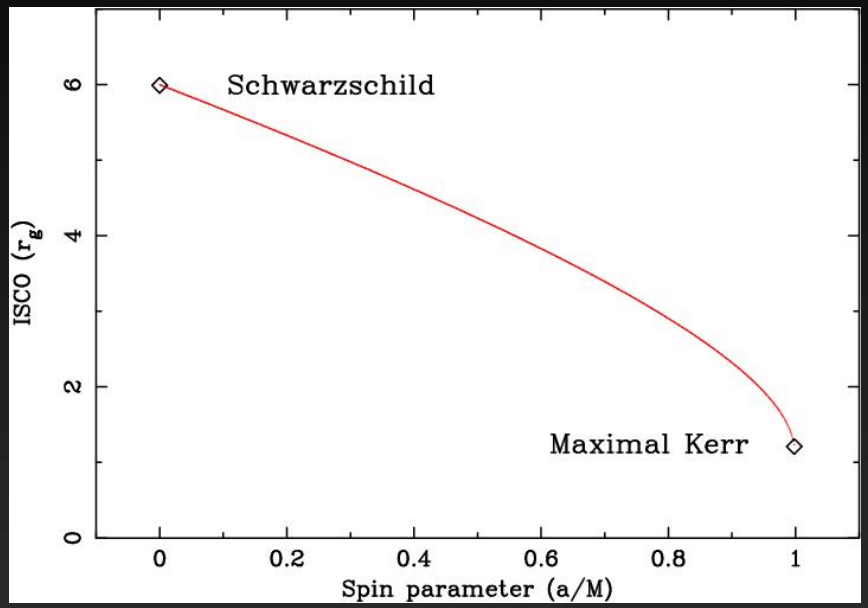


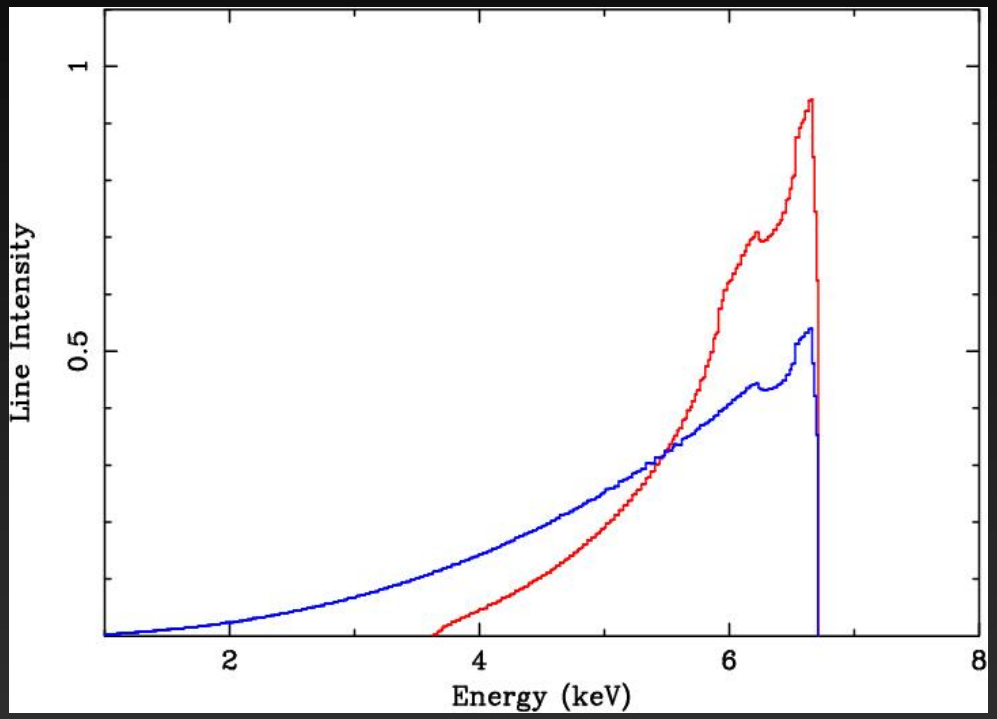
Iwasawa et al 96

CENTRO DE ASTROBIOLOGÍA

The usual suspect: MCG-6-30-15

BH spin measurements rely on the id. ISCO ≅ R_{in}

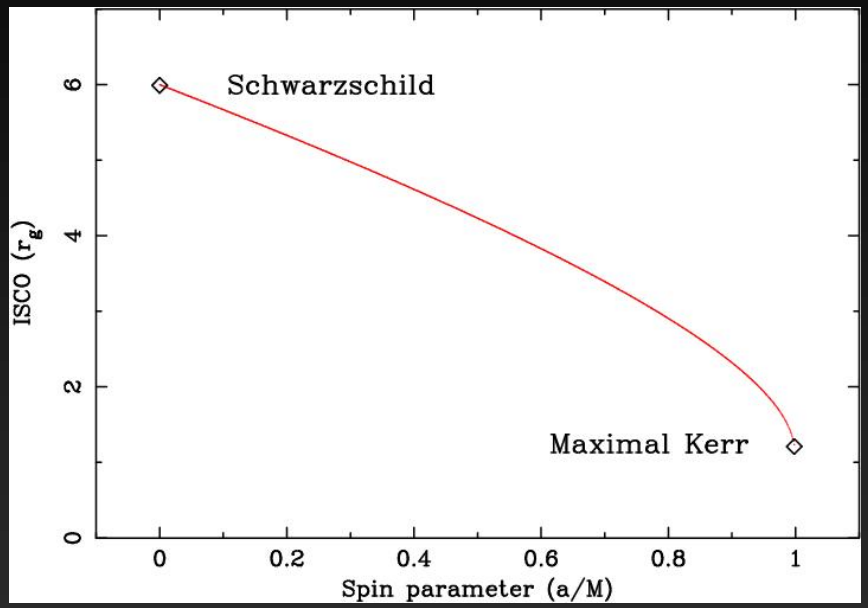


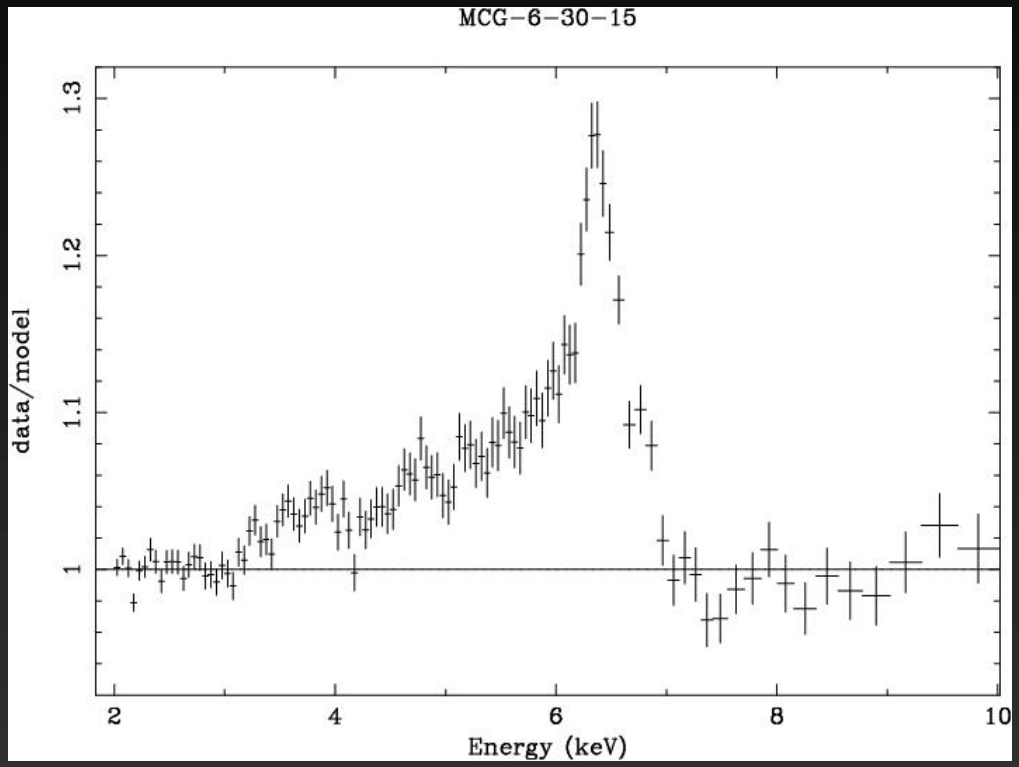


CENTRO DE ASTROBIOLOGÍA

The usual suspect: MCG-6-30-15

BH spin measurements rely on the id. ISCO ≅ R_{in}





Early results in MCG-6 indicate that $R_{in} < 2\ r_g$
which translates into a BH spin of $a > 0.94$

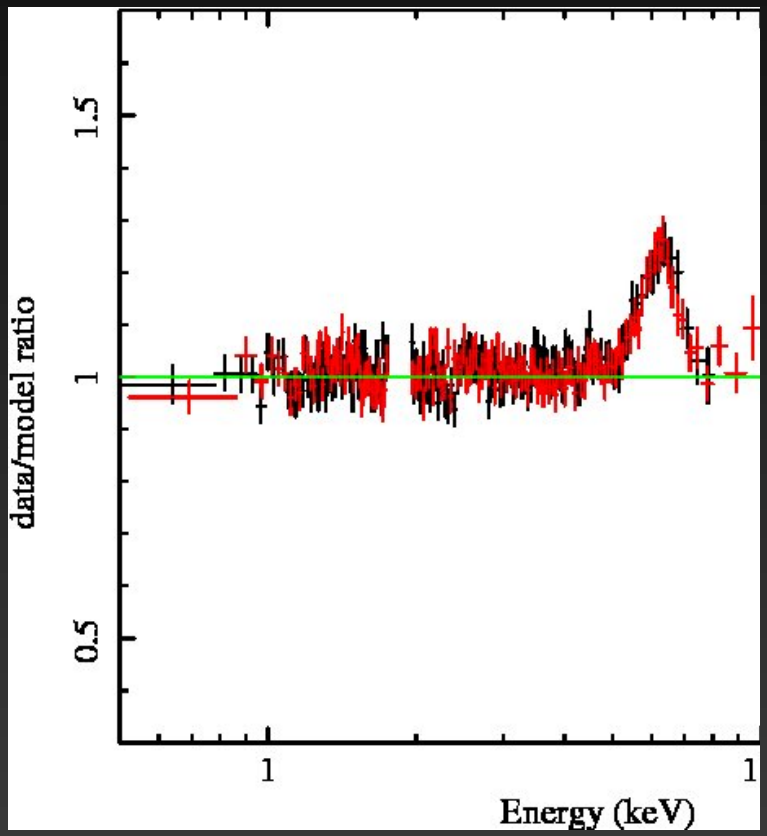
Fabian et al 02

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

This is a NLS1 galaxy detected above 20 keV with INTEGRAL/IBIS (rare)

The hard X-ray flux (~ 2.5 10^{-11} in 20-100 keV) makes it a good Suzaku source (especially for the HXD)

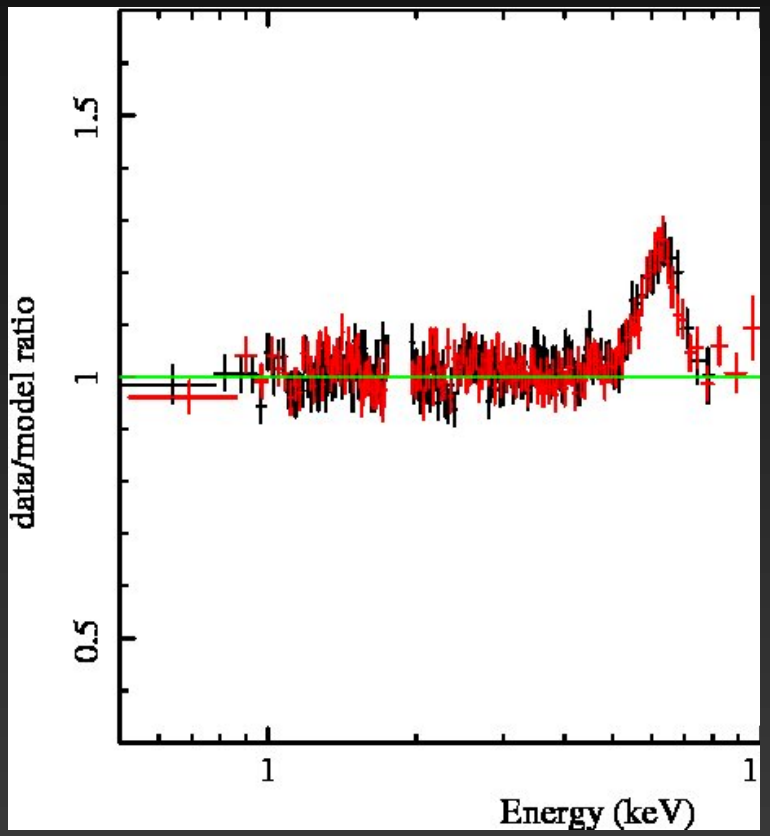


GM et al 09

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

The relativistic Fe K line should be associated with a full X-ray reflection spectrum which shows up at > 10 keV (Compton hump)

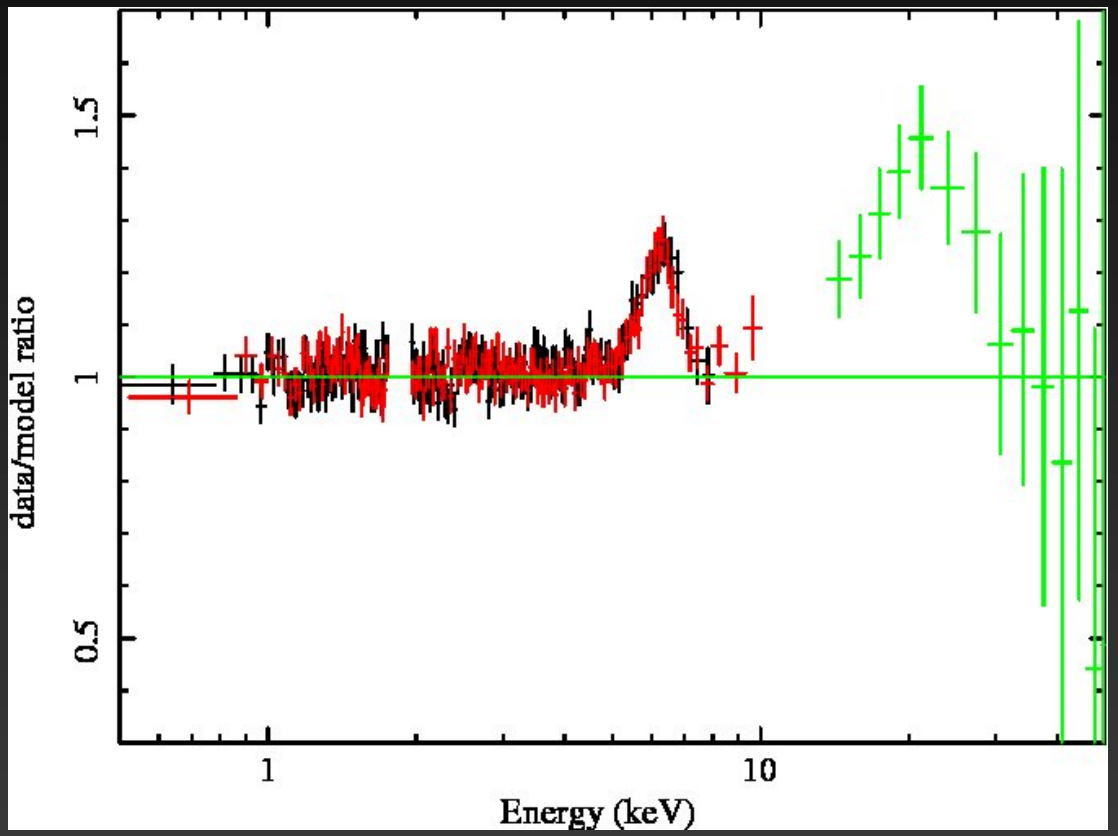


GM et al 09

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

The relativistic Fe K line should be associated with a full X-ray reflection spectrum which shows up at > 10 keV (Compton hump)

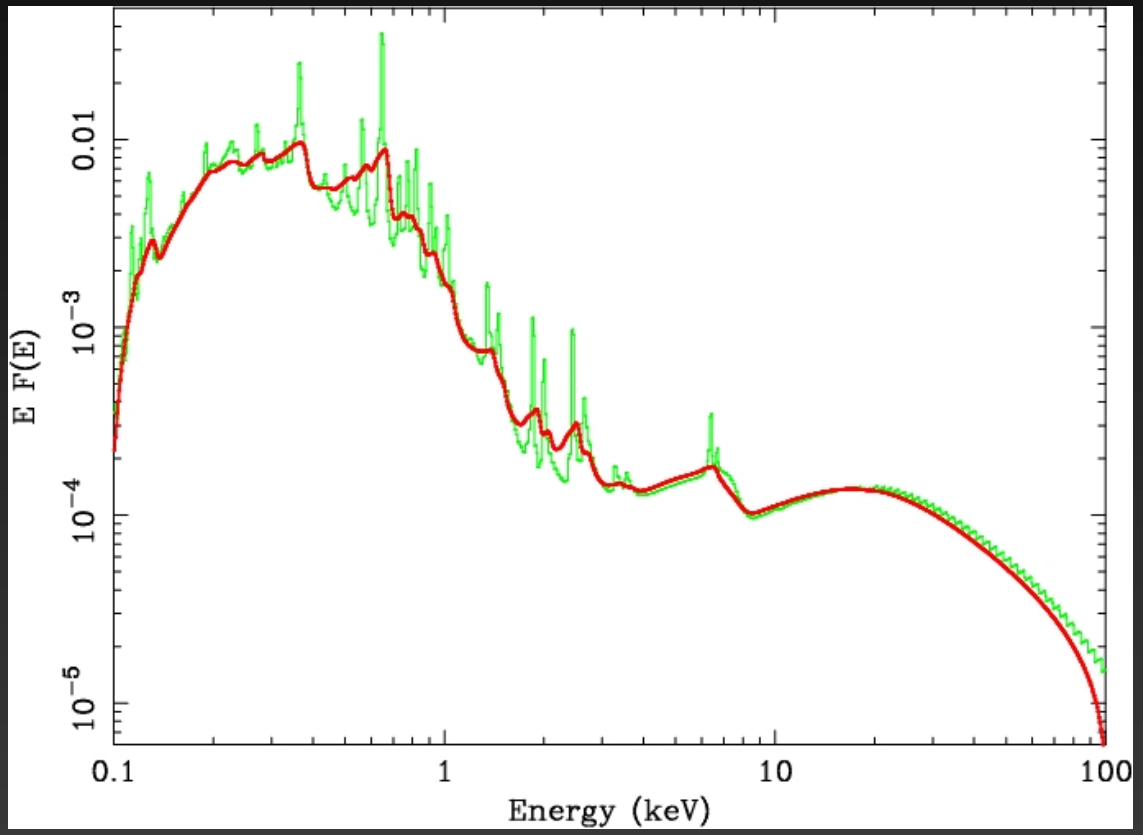


GM et al 09

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

We then used a ionized reflection model (Ross & ACF 05) to account for the whole broadband spectrum to get the spin



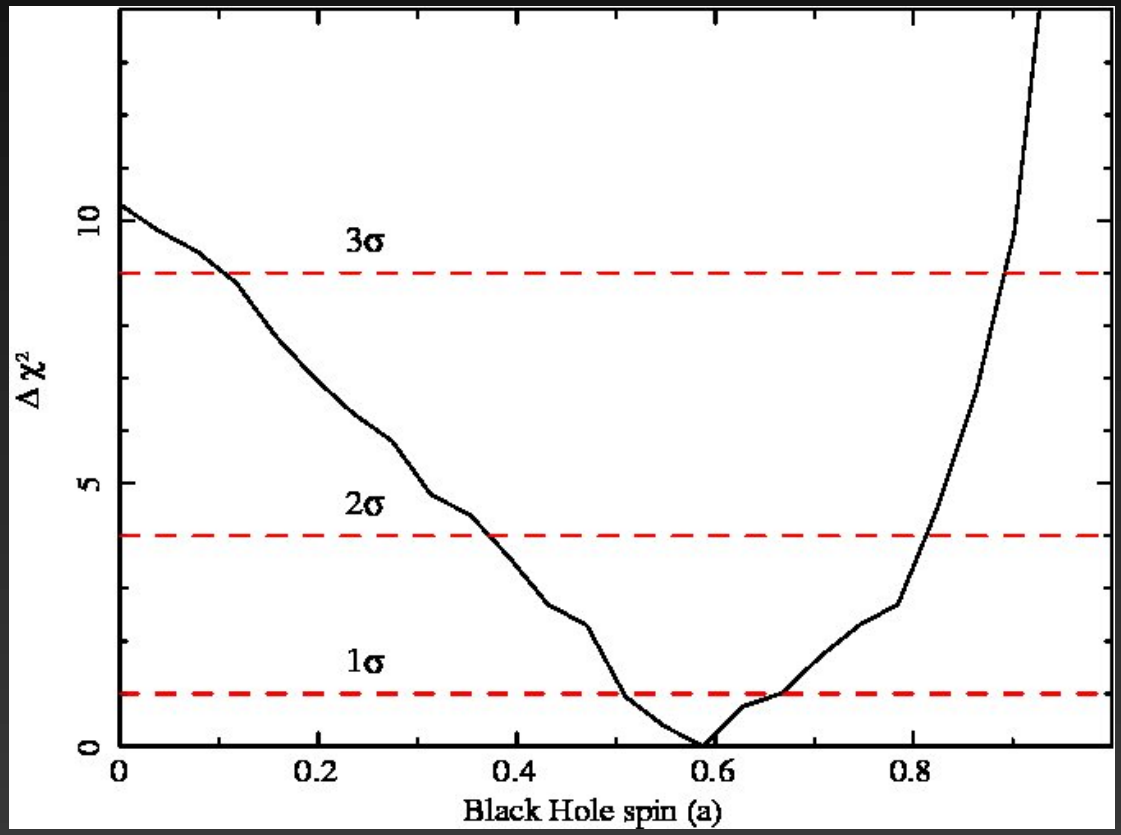
Ross & Fabian 05

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

The broadband analysis confirms results from Fe K diagnostics

a ~ 0 is excluded but just at the 3σ level
a ~ 0.998 is excluded at more than 5σ



GM et al 09

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

BH accreting more than ~ ½ of their mass should be maximally spinning
this can then be excluded

a relatively recent major merger could result in an intermediate spin

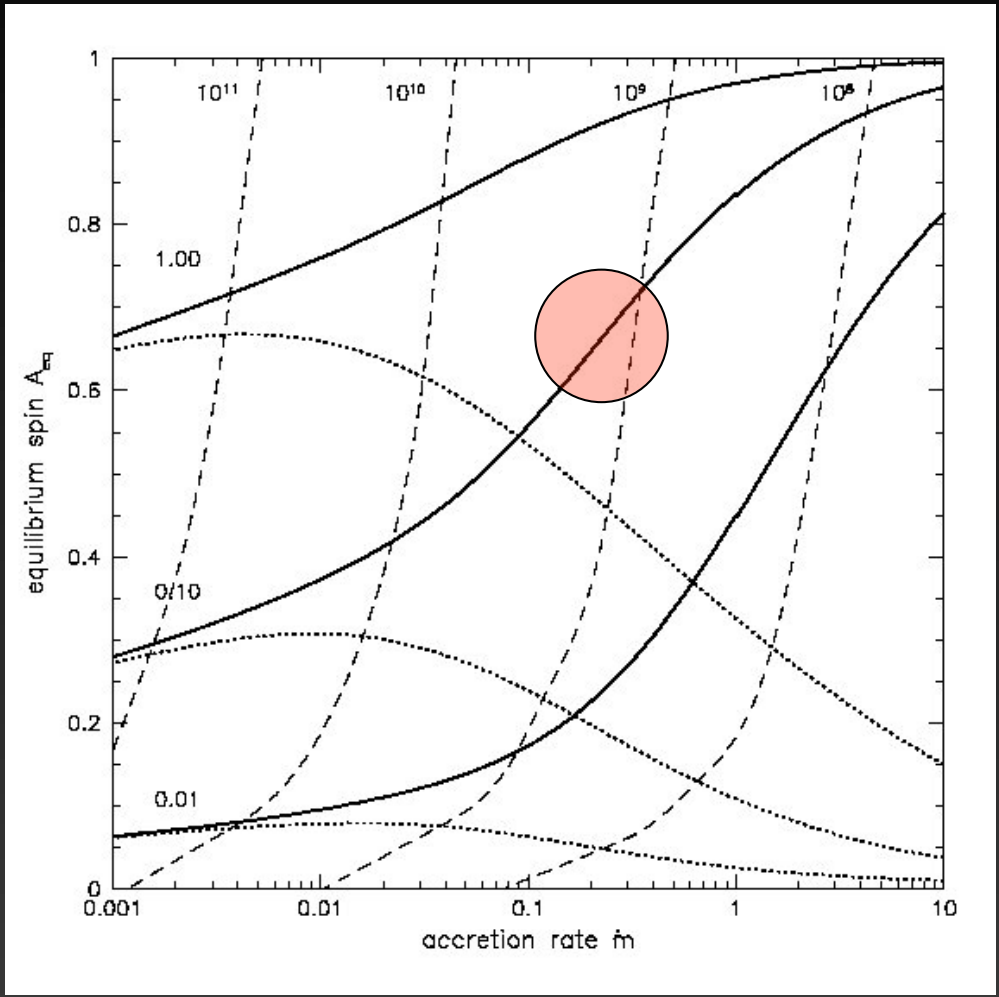
a~0 cannot be excluded with high significance (but 120ks XMM coming ...)
it could be that BH growth proceeds here via chaotic accretion

a further possibility: magnetic extraction of rotational energy (BZ) ?

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

a further possibility: magnetic extraction of rotational energy (BZ) ?



Indeed, if we consider a standard α ~0.1 disc coupled with the mass accretion rate of the object (~0.2) the system should reach an equilibrium value of a~0.5-0.6, not far from what we get

Moderski, Sikora & Lasota 98

CENTRO DE ASTROBIOLOGÍA

Fairall 9 with Suzaku

Now a standard broad line Seyfert 1

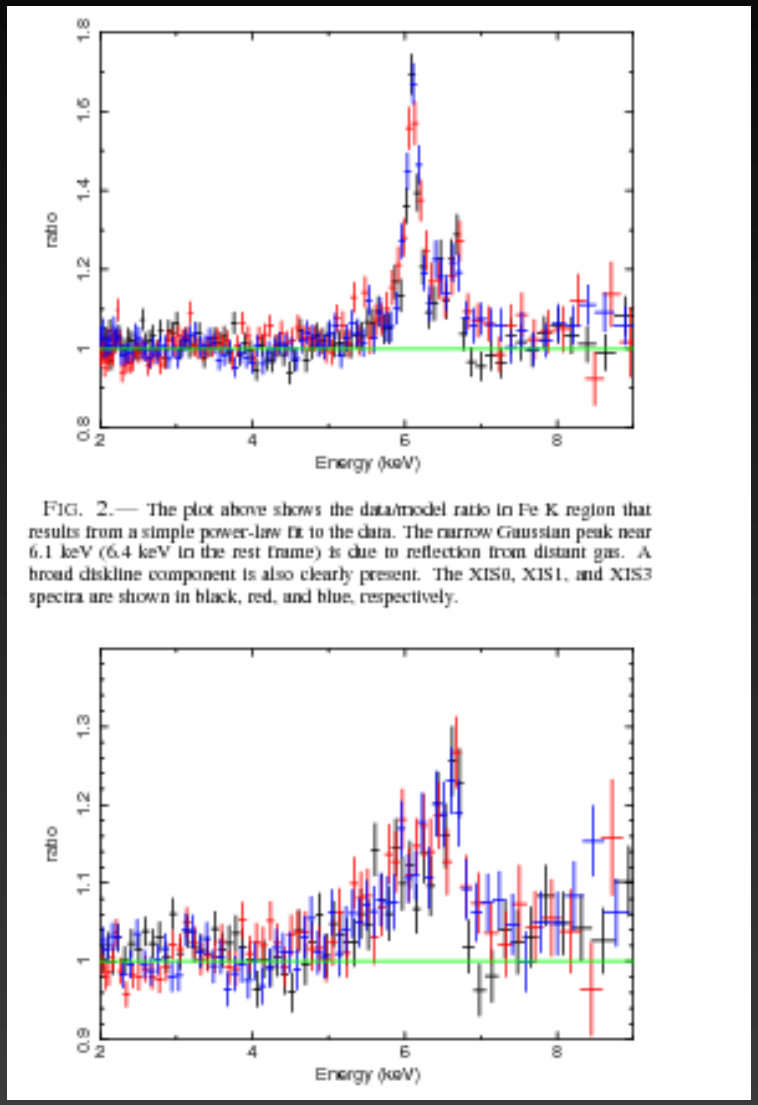
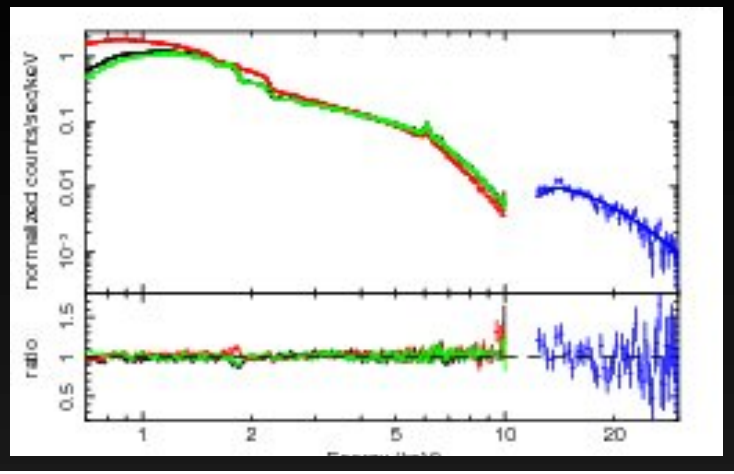
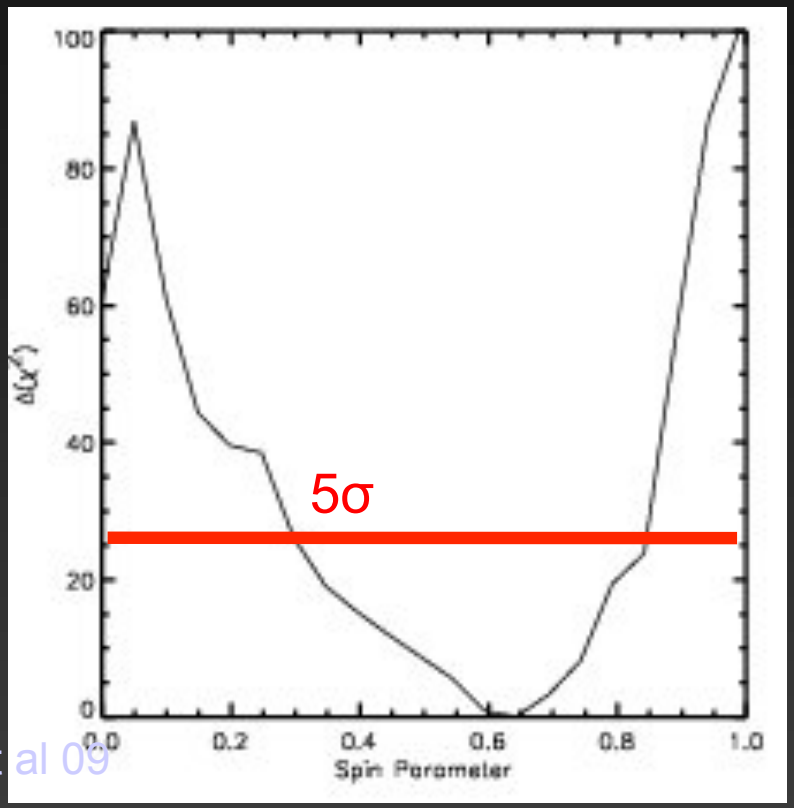


FIG. 2.— The plot above shows the data/model ratio in Fe K region that results from a simple power-law fit to the data. The narrow Gaussian peak near 6.1 keV (6.4 keV in the rest frame) is due to reflection from distant gas. A broad diskline component is also clearly present. The XIS0, XIS1, and XIS3 spectra are shown in black, red, and blue, respectively.





Schmoll et al 09

CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

This is an AGN belonging to the class of NLS1 galaxies

It is remarkable in the X-rays:

large amplitude and fast X-ray variability

huge soft X-ray excess

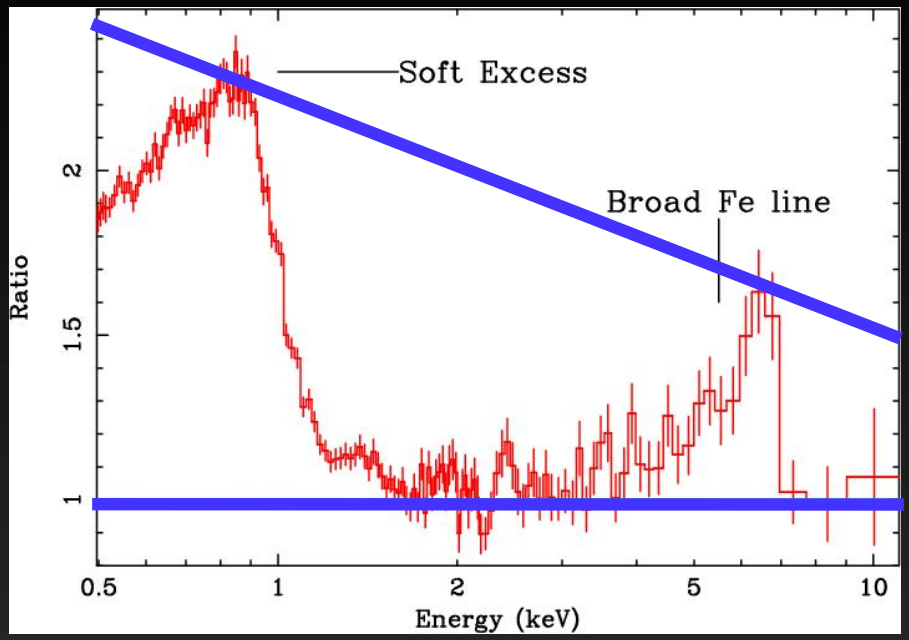
extreme spectral curvature at Fe energies (Boller et al 02)

All these properties are observed in almost all (unobscured) AGN to a much lesser extent

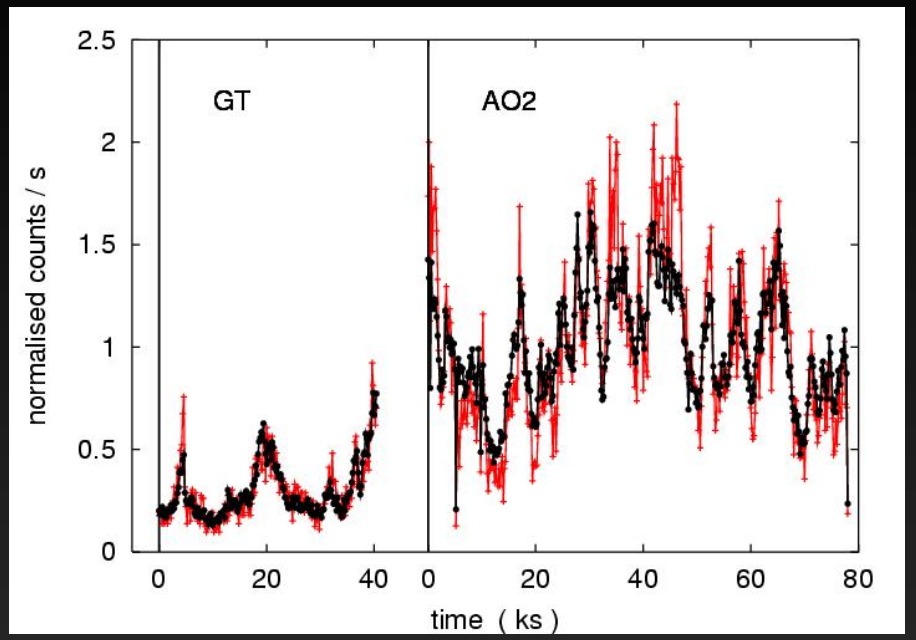
but Nature seems to have found one (actually two…) extreme object for us to study to perhaps infer the general properties of all of them

CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495



Fabian, GM et al 04



Fabian, GM et al 04

Two main competing interpretations:

absorption

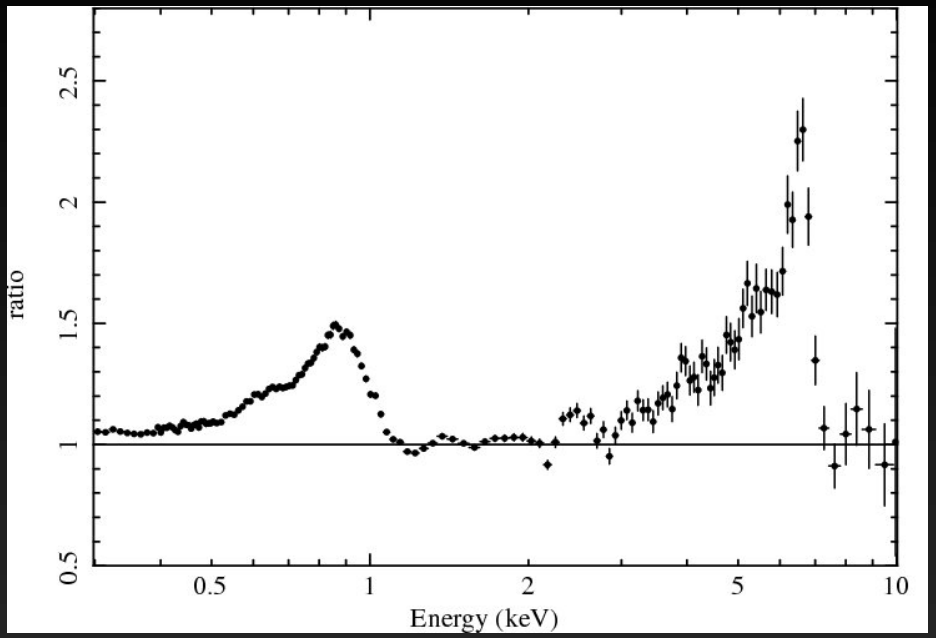
reflection

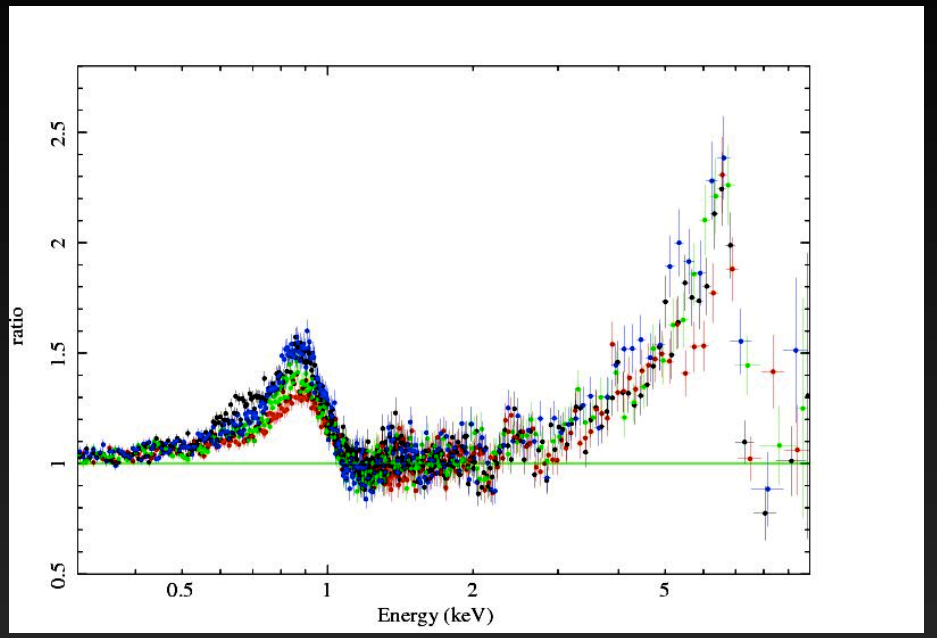
but distinguishing between the two models spectroscopically is difficult if not impossible

CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

Fabian et al 09; Zoghbi et al 10





ratios of the data to a simple power law + BB model

time-averaged orbit by orbit

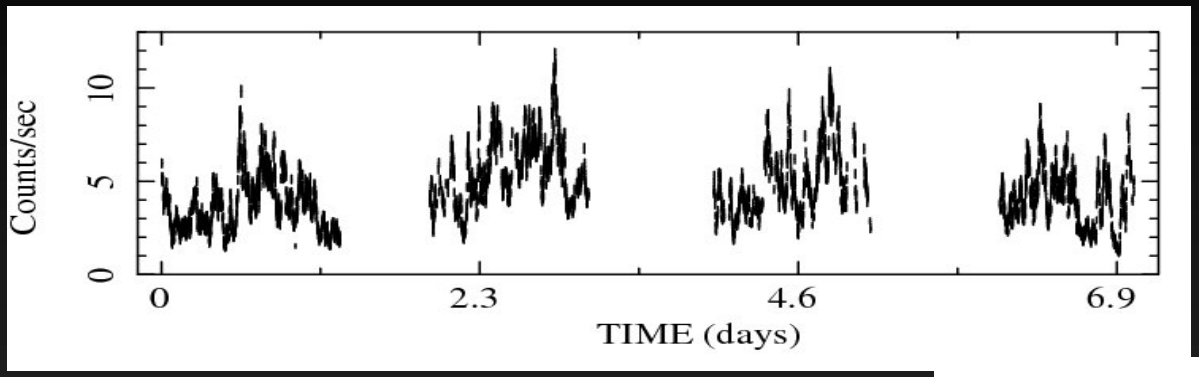
two unambiguous features appear between 0.6-1 keV and 4-7 keV

and they can be interpreted as broad Fe L and K lines coming from the same medium with huge reflection fraction and high Fe abundance

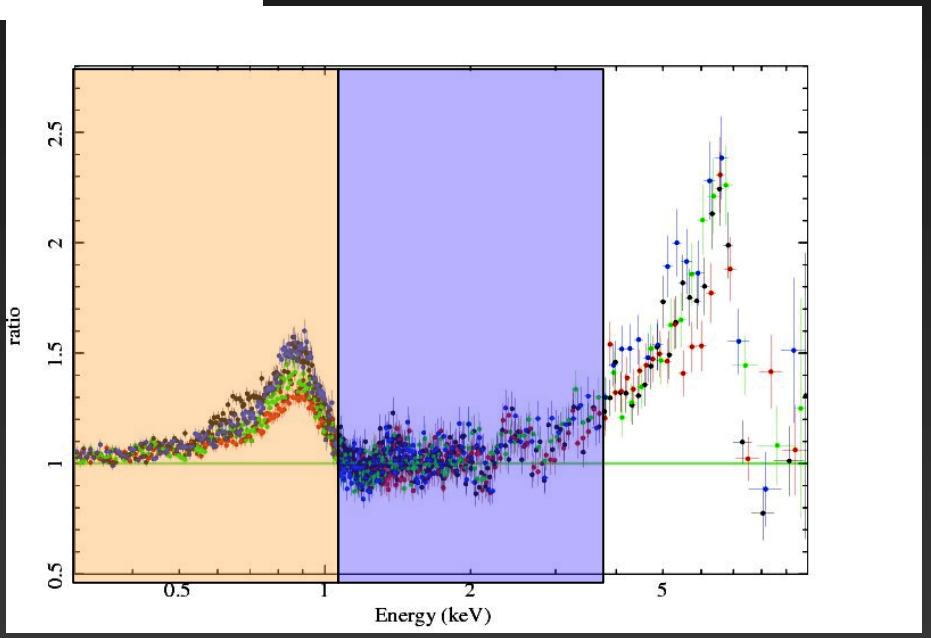
CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

Again absorption models may work, but what about variability?



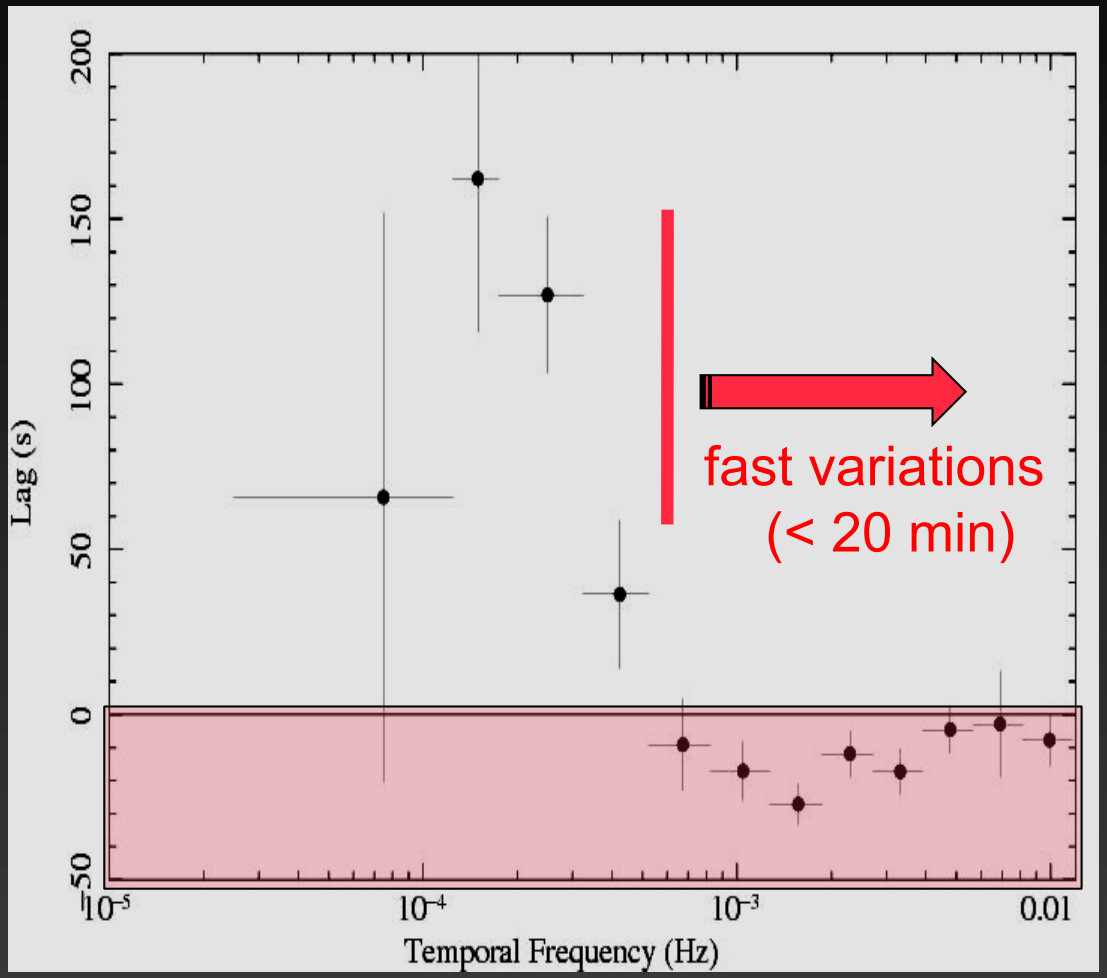
the two competitors
(absorption and reflection)
predict very distinct properties



CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

Looking for time lags between lines and continuum: the most crucial result

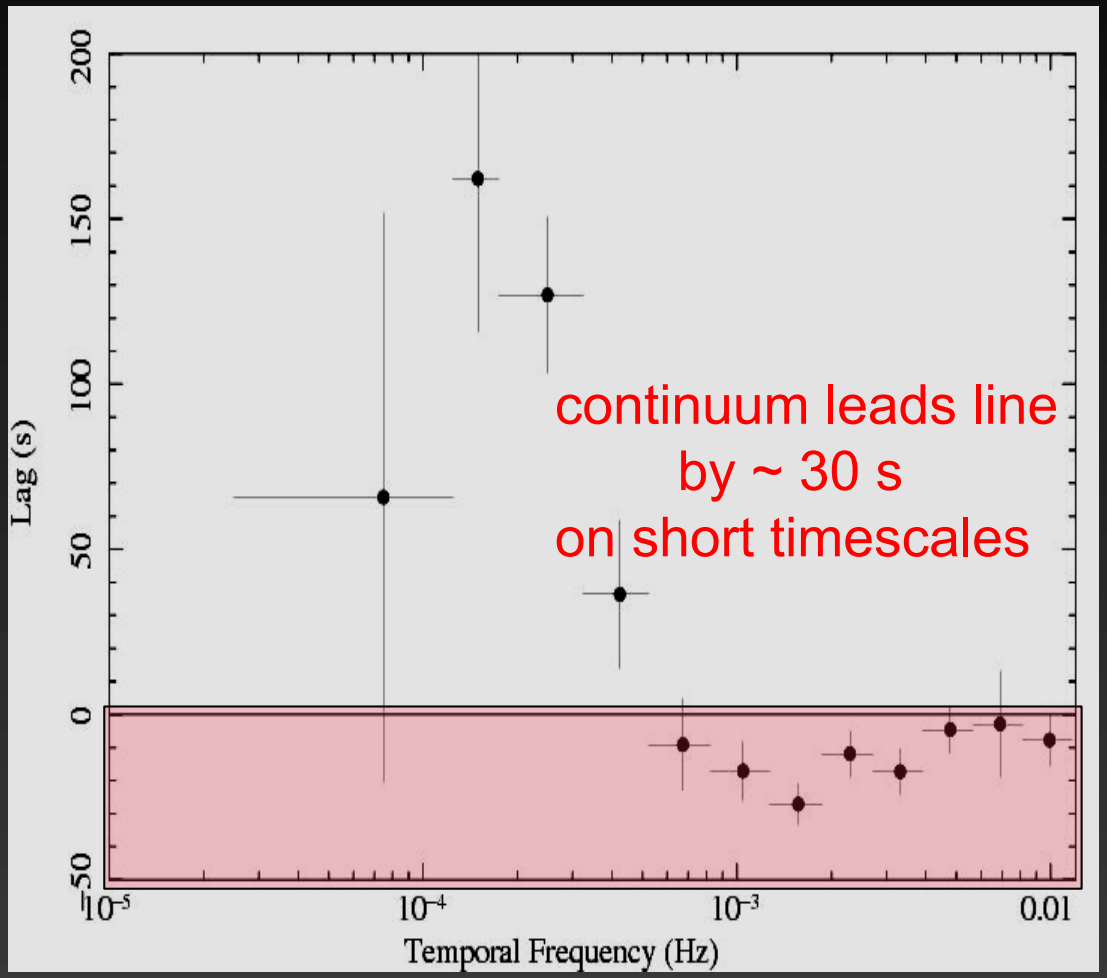


Fabian et al 09

CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

Looking for time lags between lines and continuum: the most crucial result



Fabian et al 09

CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

The observed lag means that

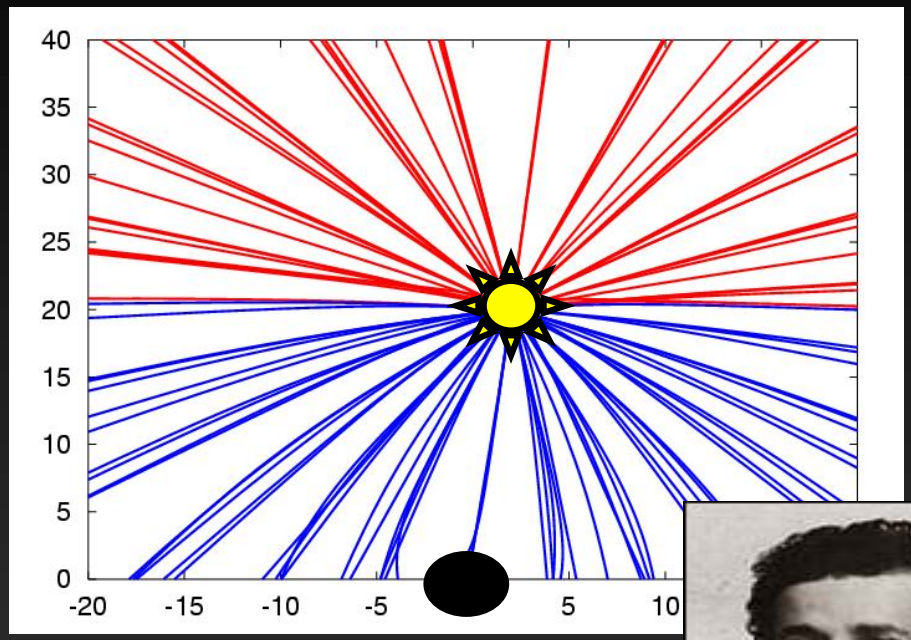
- the soft X-ray spectrum (Fe L) has to be reprocessed emission
- if it was the same continuum the lag would be in the opposite direction
- absorption is then ruled out
- the magnitude of the lag (~ 30s) is dictated by light travel time:
  - the X-ray corona is very close to the BH (few r_g)
  - the BH mass is likely 3-5 x 10^6 $M_\odot$

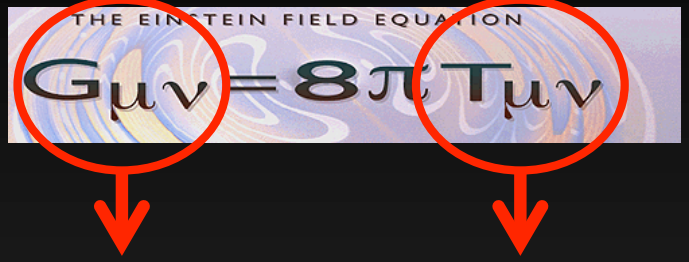
CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

Problem: why is reflection so strong?

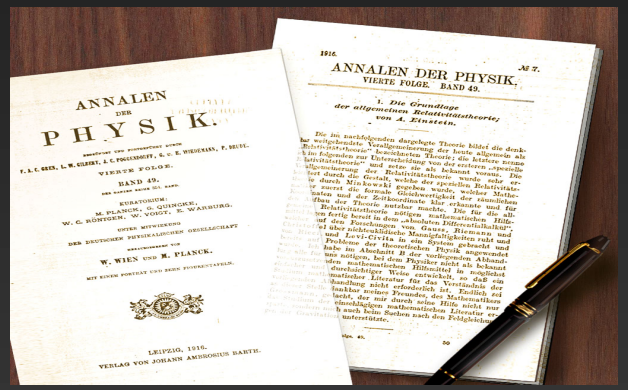
GM & Fabian 04





geometry energy

Einstein
1879-195
5



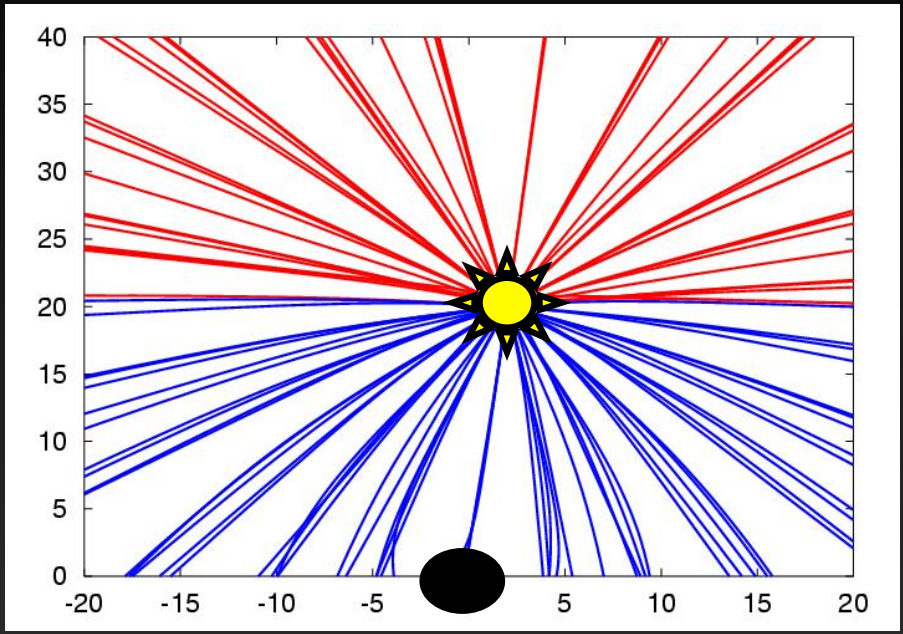
General Relativity
1916

CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

Problem: why is reflection so strong?

GM & Fabian 04



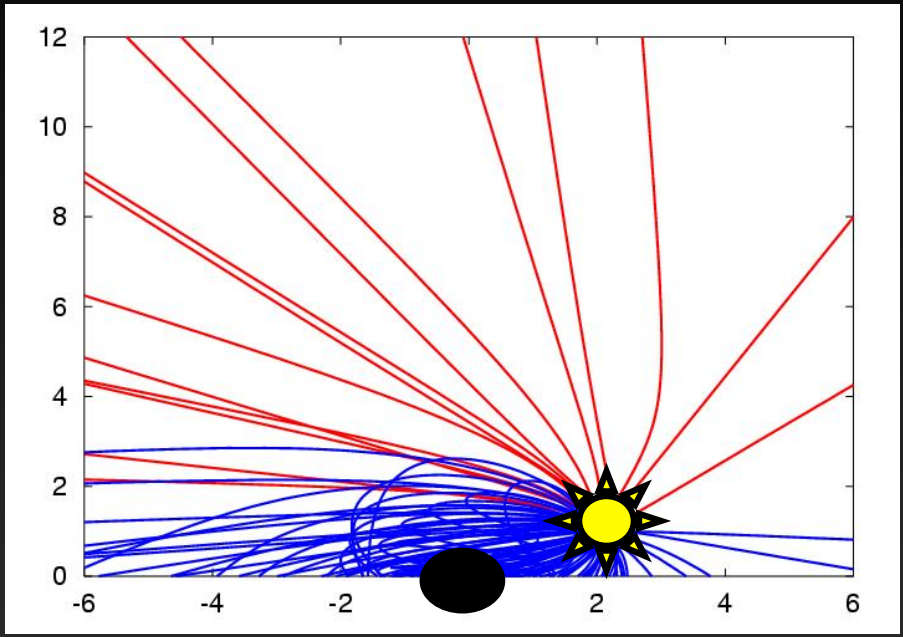
GR light bending

CENTRO DE ASTROBIOLOGÍA

The special case of 1H 0707-495

Problem: why is reflection so strong?

GM & Fabian 04



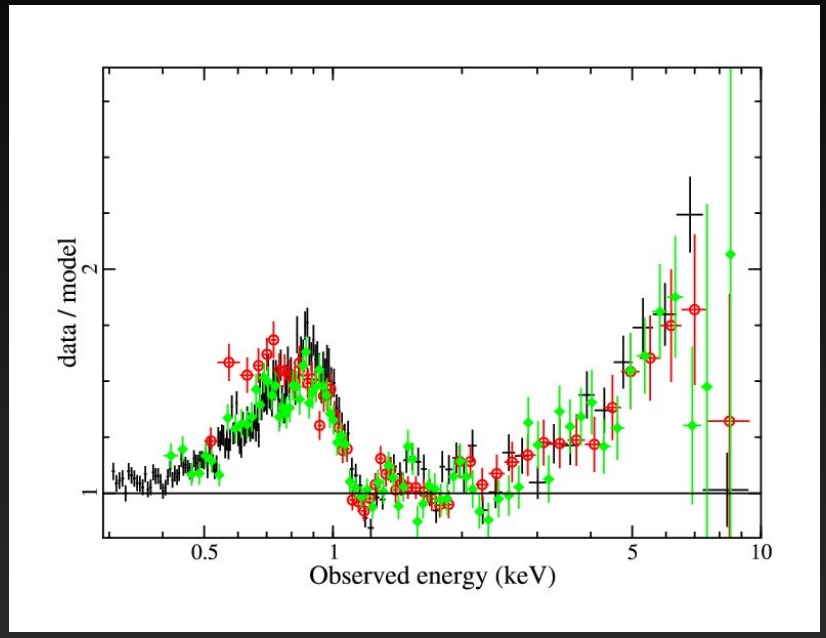
It is a natural consequence of having a X-ray corona close to the BH as demonstrated by the ~30s lag

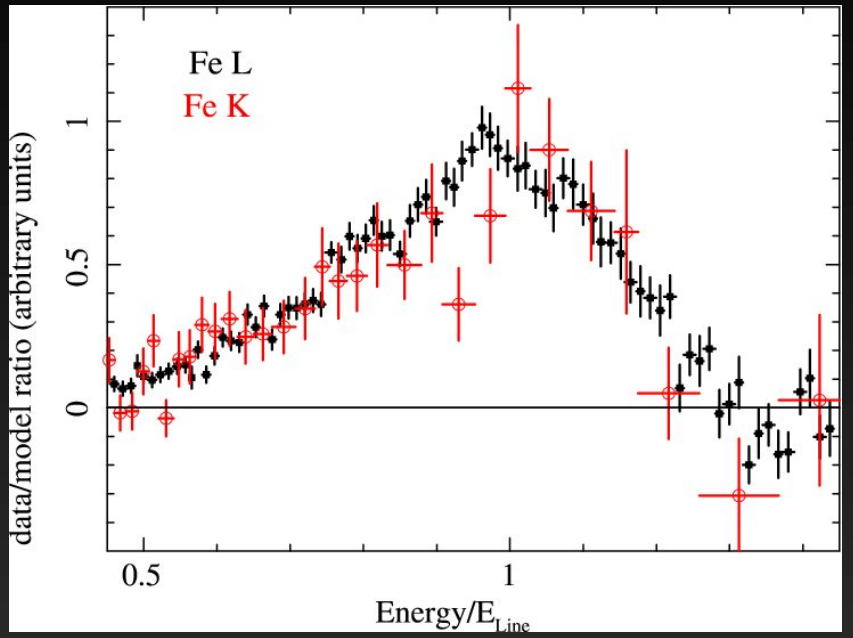
GR light bending

CENTRO DE ASTROBIOLOGÍA

Is 1H 0707-495 a unique case ?

Well, there is another suspect: IRAS 13324-3809



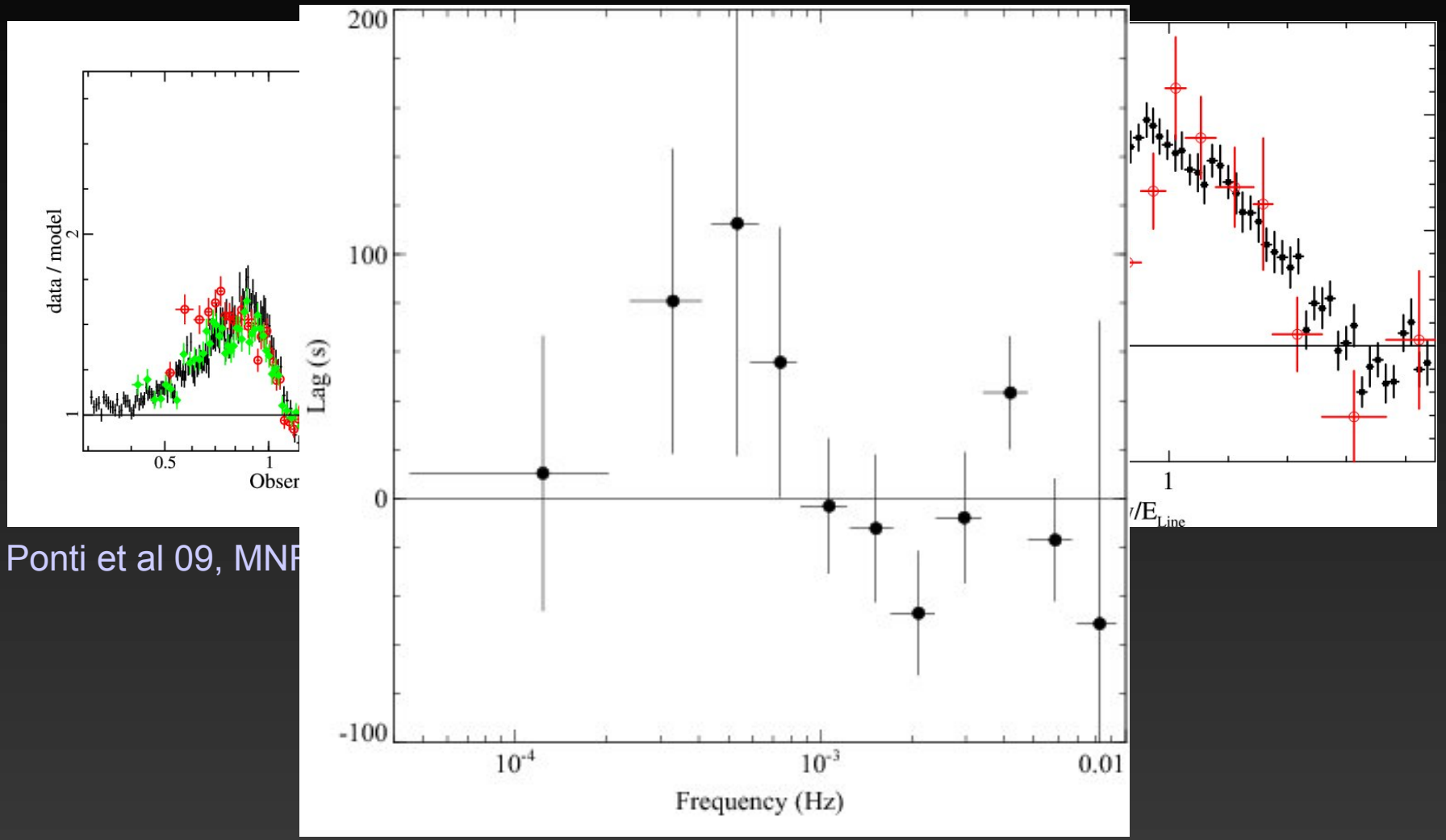


Ponti et al 2010, MNRAS in press

CENTRO DE ASTROBIOLOGÍA

Is 1H 0707-495 a unique case ?

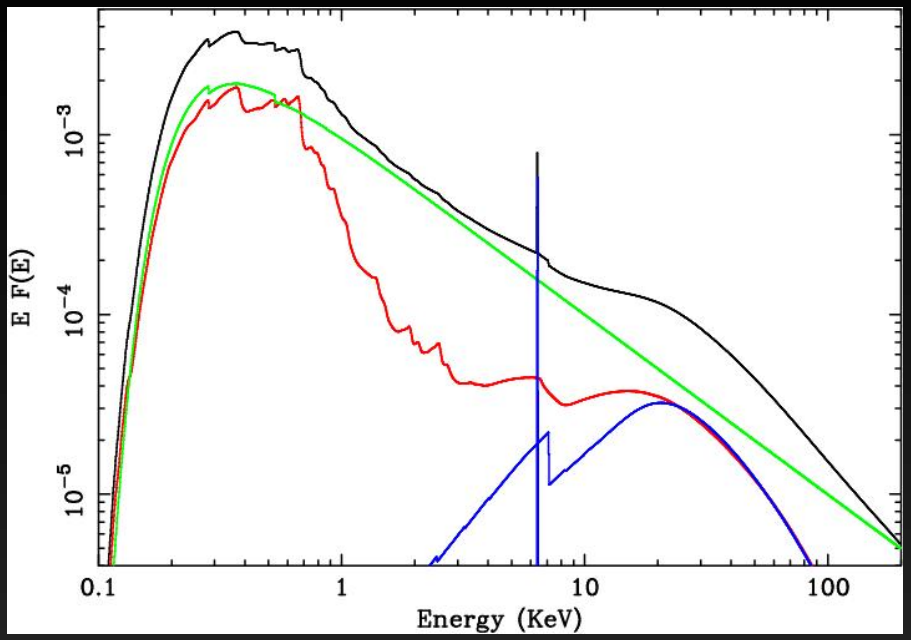
Well, there is another suspect: IRAS 13324-3809

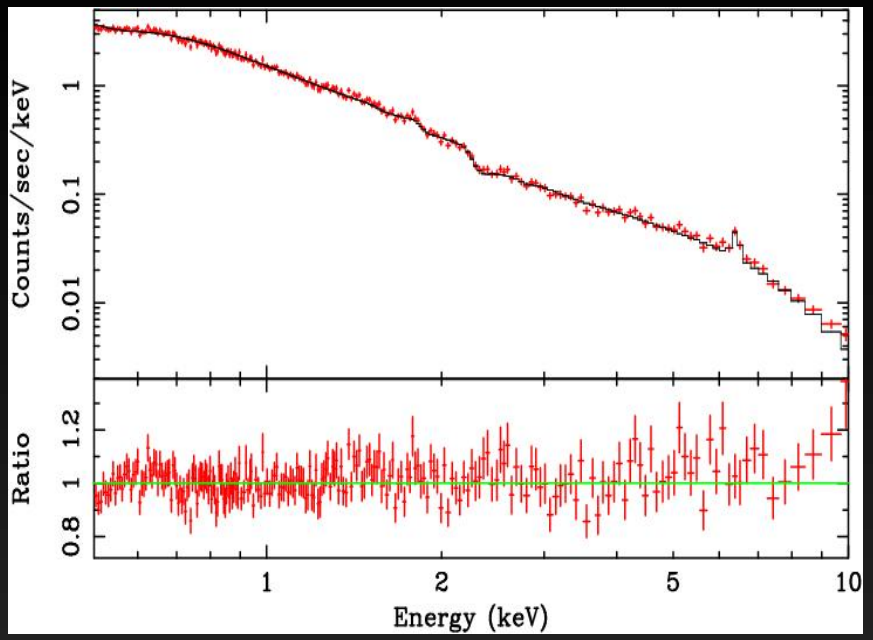


Ponti et al 09, MNR

CENTRO DE ASTROBIOLOGÍA

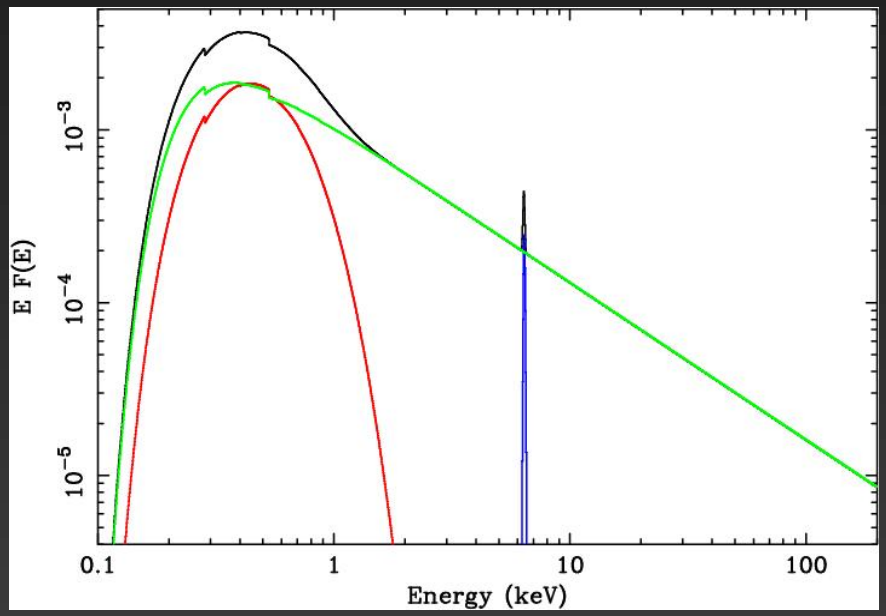
Conclusions: do we have a template ?





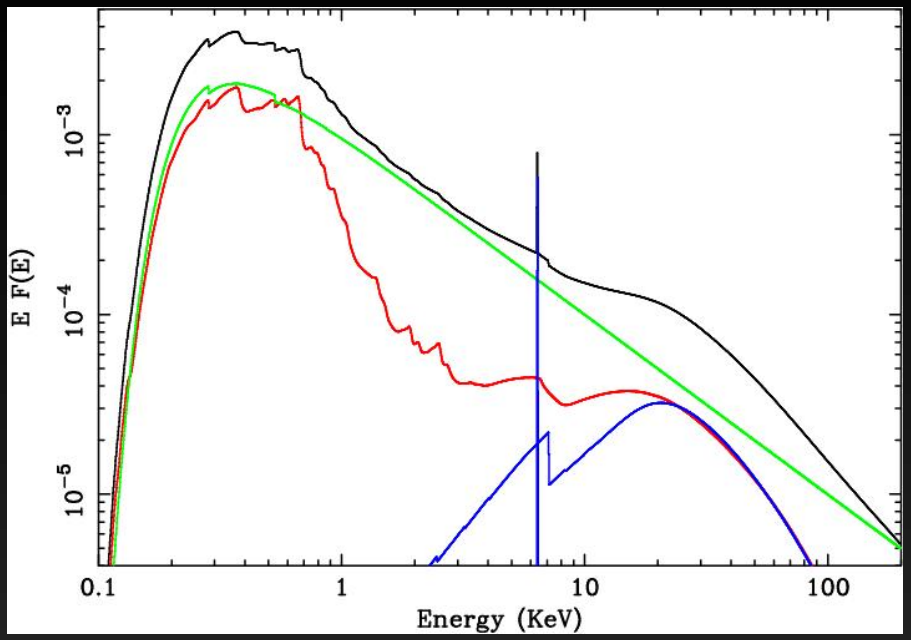
What a standard one would look like

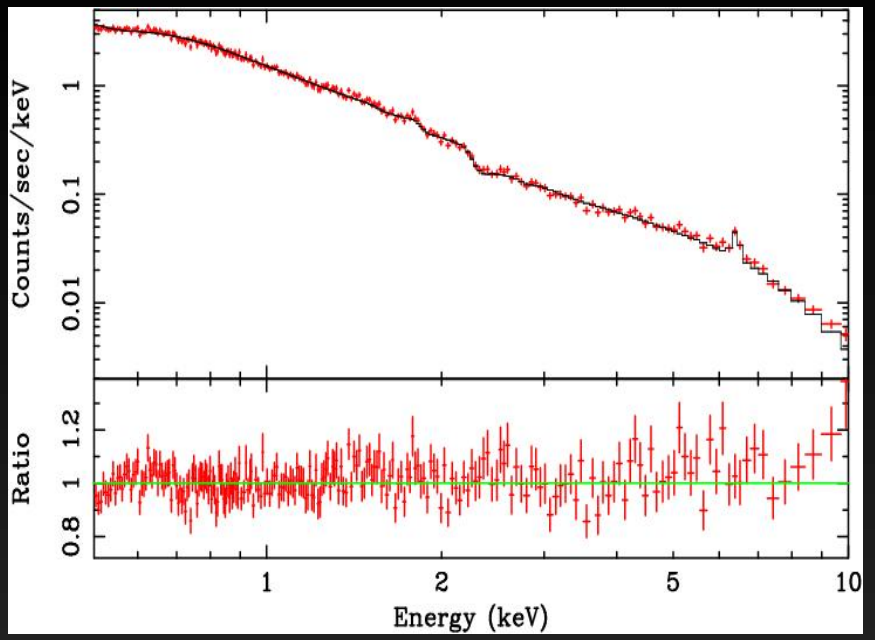
In the standard situation and with normal exposures we are unable to detect all these features except for the soft excess (which is indeed ~ ubiquitously detected)



CENTRO DE ASTROBIOLOGÍA

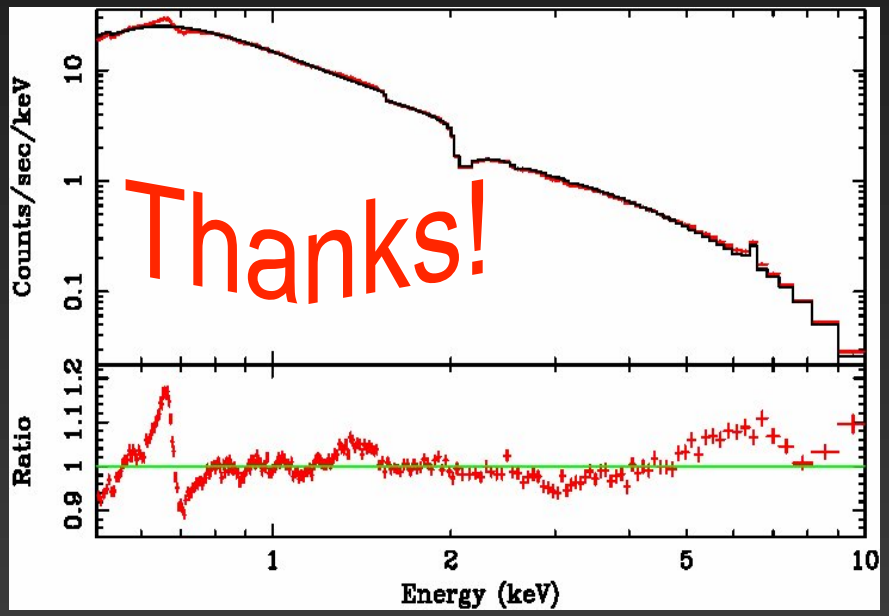
Conclusions: do we have a template ?





What a standard one would look like

In the standard situation and with normal exposures we are unable to detect all these features except for the soft excess (which is indeed ~ ubiquitously detected)



Thanks!